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SELECTED WATER RESOURCES ABSTRACTS
INPUT TRANSACTION FORM

1. Report No. 2. W 72-12631

SEWAGE SLUDGE INCINERATION,

5. Report Date
6.
8. Performing Organization Report No.

EPA Program Element B 12043

Environmental Protection Agency, Washington, D. C., Task Force of Sewage Sludge Incineration

12. Sponsoring Organization

13. Type of Report and Period Covered

Environmental Protection Agency Report No. EPA-R2-72-040, August 1972, 89 p, 2 fig, 10 tabs, 5 ref, 9 append

A Task Force was established within the Environmental Protection Agency to evaluate sludge incineration as an acceptable alternative to sea disposal. Multiple-hearth and fluidized bed furnaces, containing scubbing devices for particulate removal, were selected for performance evaluation. The sludge, particulate, stack gas, scrubbing liquid, and ash were sampled, and analyzed for heavy metals, pesticides and oxides of nitrogen and sulfur. The results indicated that incinerators are capable of achieving low emi ion concentrations for the common pollutants. Particulate samples showed a measurable concentration of lead. The ash samples normally showed a higher concentration of the heavy metals when ~~normally showed a higher concentration of the heavy metals when~~ compared with the sludge samples, however, mercury was one of the exceptions and was not detectable in the ash sample and assumed as lost to the stack gases. The pesticides and PCB, present in the sludge, were not detectable in either the ash or the scrubbing water, and indicated complete destruction. The study demonstrated that well designed and operated municipal sewage sludge incinerators can meet the most stringent existing particulate emission control regulation. ([redacted] (EPA abstract)

17a. Descriptors: *Incineration, *Ultimate Disposal, *Sludge Disposal, *Waste treatment, Air pollution effects, Sludge, Pesticide Removal, Heavy metals, Polychlorinated biphenyls

17b. Identifiers: *Multiple hearth furnaces, *Fluidized bed incinerators, Stack emissions, Ocean disposal, Particulate removal

Available from the National Technical Information Service as PB 211 523.

17c. COSATI Field/Group 05D, 05E

19. Security Class. (Report)
20. Security Class. (Page)
21. No. of Pages
22. Price

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WATER RESOURCES SCIENTIFIC INFORMATION CENTER
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ABSTRACT

A Task Force was established within the Environmental Protection Agency to evaluate sludge incineration as an acceptable alternative to sea disposal. Multiple-hearth and fluidized bed furnaces, containing scrubbing devices for particulate removal, were selected for performance evaluation. The sludge, particulate, stack gas, scrubbing liquid, and ash were sampled, and analyzed for heavy metals, pesticides and oxides of nitrogen and sulfur. The results indicated that incinerators are capable of achieving low emission concentrations for the common pollutants. Particulate samples showed a measurable concentration of lead. The ash samples normally showed a higher concentration of the heavy metals when compared with the sludge samples, however, mercury was one of the exceptions and was not detectable in the ash sample and assumed as lost to the stack gases. The pesticides and PCB, present in the sludge, were not detectable in either the ash or the scrubbing water, and indicated complete destruction. The study demonstrated that well designed and operated municipal sewage sludge incinerators can meet the most stringent existing particulate emission control regulation.

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REPORT

ENVIRONMENTAL PROTECTION AGENCY

TASK FORCE ON SEWAGE SLUDGE INCINERATION

January 1972

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SECTION I

ENVIRONMENTAL PROTECTION AGENCY

TASK FORCE ON SEWAGE SLUDGE INCINERATION

Task Force Observations and Conclusions

1. When operated properly, today's sludge incinerator systems, which have been designed to meet existing air quality standards, have been shown by test to produce acceptable stack emissions of particulate matter, nitrogen oxides, sulfur oxides and odors. This was true for both fluidized bed and multiple hearth type incinerators. Most sludge incinerators which are in existence today, however, do not incorporate high efficiency particulate matter control devices.

2. Small, but measurable, quantities of specific metals which are known to accumulate in the human system, and which are known to be toxic at certain levels, were found in the input sludge, stack emissions, scrubber water, and residue of those incinerators which were subjected to comprehensive testing under Task Force supervision. These same metals were also found in each instance where only the sludge alone was analyzed.

3. Small, but measurable, quantities of specific organic chemical compounds including various pesticides and polychlorinated biphenyls, which are known to accumulate in the human system, were found in all of the sludge samples analyzed. It should be expected that, under conditions of poor combustion, such compounds could be emitted from the stacks of sewage sludge incinerators.

4. It was impossible for the Task Force to accurately establish the potential for health effects which might be associated with sewage sludge incineration because:

a. There are insufficient health effects data relating to low atmospheric concentrations of suspected pollutant materials including certain elements such as Cadmium, Arsenic, Beryllium, Nickel, Copper, Lead Chromium, Vanadium, and Mercury, Organic Pesticides, and Polychlorinated Biphenyls.

b. There are insufficient stack gas sampling and analysis methods sophisticated enough to produce accurate information regarding the quantity, size distribution, and constituent quality related to size, of the particulate matter emitted by sewage sludge incinerators.

Section II
INTRODUCTION AND SUMMARY

More and more, as action is taken to solve environmental problems, it is discovered that the solutions chosen have produced new and different problems. Such is the case concerning the ultimate disposal of sludge from sewage treatment plants.

Primary sewage treatment is designed to remove the bulk of the solids present in the sewage. The removed solids, in the form of sludge, are either disposed of directly from the primary process or receive their final disposal after combination with sludges from secondary treatment processes.

In certain areas, particularly on the East Coast, the practice has been to barge sewage sludge to sea, for ultimate disposal into the ocean depths. It is this form of disposal which has, over the past year, been the subject of official concern and action because of its apparent adverse affect upon life on the ocean floor.

In October 1970, the Council on Environmental Quality recommended, in its "Ocean Dumping - A National Policy", that ocean dumping of sludge should be phased out as an ultimate disposal practice. The State of New Jersey has taken strong legal steps to curtail sludge dumping at sea and, at last count in September 1971 , 39 House of Representatives and 4 Senate bills, to restrict ocean dumping, were under consideration by Congress.

If, as appears likely, unrestricted disposal at sea will not continue to be an acceptable practice for sludge removed in sewage treatment plant operations, what alternatives exist? In order to give searching consideration to this question, the Environmental Protection Agency established two

separate task forces in the spring of 1971. Each task force included representation from all fields of environmental control, with special involvement from the Office of Water Programs, Office of Air Programs, and the Office of Research and Monitoring.

One EPA Task Force was set up to examine all of the alternatives for sewage sludge disposal, and to recommend those methods which will not result in an objectionable impact on the environment. The second Task Force was charged with the responsibility of determining whether or not the sludge incineration alternative is acceptable at this time. This question is immediately important because incineration will become the likely choice for sludge disposal by communities presently barging their sludge to sea if ocean dumping is prohibited outright.

Incineration of sludge, of course, has an inherent potential for air pollution; it is this potential which has dominated the thinking of the Environmental Protection Agency Sewage Sludge Incineration Task Force. At the first meeting of the Task Force, in June 1971, it was agreed that two basic questions must be answered by the group: (1) Can the environment tolerate the expected impact upon it resulting from the incineration of sludge?, and (2) If the answer to the first question is affirmative, what can be recommended as the best available sludge incinerator technology?

To provide information upon which answers to the basic questions could be formulated, the following Task Force program was established:

1. Develop data regarding emissions into the atmosphere from existing sewage sludge incinerators. Qualitative and quantitative information would be gathered from a variety of incinerator types handling a variety of sludge types.

2. Develop data regarding potential emissions into the atmosphere, based upon analyses of sewage sludge content entering existing incinerators. The analyses would be made for major pollutant materials of concern, with special emphasis upon health-effects-related pollutants.

3. Examine characteristics of incinerated sludge residue to provide information for ultimate disposal of the ash.

4. Review anticipated technology involving combustion processes for sludge, in order to make recommendations for pilot plant efforts which go beyond existing incinerator types.

It was decided by the Task Force that sampling analyses at existing incinerator sites should include the major metals and such materials as PCB (Polychlorinated Byphenyls) as well as the more common air pollutants. This decision was made because of the importance that must be given to health-effects-related compounds.

As the Task Force study program got underway, 16 existing sludge incinerators across the country received preliminary investigation. Of these 16, 5 were of the fluidized bed type and 11 were multiple hearth incinerators. All of the incinerators incorporated scrubbing devices for control of particulate matter. As a result of this initial examination, 3 incinerators were chosen for detailed sampling and analysis. These 3 were at Barstow, California, South Lake Tahoe, California, and Lorton, Virginia. The Barstow incinerator input included only raw sludge from primary treatment; this installation utilized the fluidized bed principle. The South Lake Tahoe unit burned both sludge from the primary process and residue from an activated sludge unit; a multiple hearth incinerator was used. The Lorton, Virginia incinerator was also multiple hearth; it

handled primary sludge and grease.

A summary of the information which has resulted from the sampling program conducted at the three sites can be given as follows:

A. Stack Gas Analyses for Particulates, NO_x, SO_2, and Visible Emissions

Analyses of the stack gases indicated that none of the incinerators exceeded an overall dry filterable particulate average concentration of 0.07 grains per standard cubic foot for all test runs inclusive. In the case of the largest incinerator, handling a dry solids feed of approximately 1225 lbs/hour, as a gross average during three test runs, the mass per unit time emission did not exceed an overall average of 2.0 pounds per hour.

Oxides of nitrogen emissions were obtained only at South Lake Tahoe and Barstow, California; the higher overall test average emission concentration of the two did not exceed 175 ppm.

Sulfur oxides, again, were measured only at the California sites; measured concentrations did not exceed 13 ppm as an average emission during the test period.

Visible emissions, at all three test incinerators, were less than 10% opacity.

These test results indicate that well designed and operated sludge incinerators are able to achieve acceptably low emission concentrations for the common pollutants. It should be stated here, however, that the three test incinerators handled essentially domestic (residential) sewage loads.

B. Stack Gas Analyses for Major Metals

Measurable concentrations of metals were found in the stack gas material collected from both California sites. Measurable emissions on a mass per unit time basis included .06 pounds per hour, as a gross average of three test runs, for lead at South Lake Tahoe. Such an emission, to laymen, may seem inconsequential on an absolute basis, but lead and other elements such as cadmium, chromium, copper, nickel, and vanadium are said by Environmental Protection Agency physicians to be biologically non-degradable and toxic at certain concentrations in human tissue. All of these metals were measured in the particulate matter analyses.

C. Input Sludge Analyses

As would be expected from the stack gas samples, an examination of the input sludge showed measurable quantities of the heavy metals and other important pollutant compounds. The elements cadmium, beryllium, nickel, copper, lead, chromium, vanadium, and mercury are said by physicians to be toxic and accumulate in the human body; all, with exception of beryllium, nickel, and vanadium were found in input sludge analyses made at Barstow, South Lake Tahoe, and Lorton. Vanadium was found only at Barstow.

In addition, analyses were made for major pesticides in the input sludge at the 3 incinerator locations. At Barstow, measurable concentrations of PCB, dieldrin, Chlordane, and DDD were found. At Lorton, measurable concentrations of all of the above were uncovered. At South Lake Tahoe, only PCB was analyzed for, and was found.

D. Analyses of Incinerator Ash

For South Lake Tahoe, Barstow, and Lorton, metal analyses were also made of the ash remaining after incineration of the sewage sludge. The data showed that all of the mercury in the sludge is apparently lost in the stack gases, and that lead compounds are apparently carried off in the fly ash.

A comparison of sludge ash composition with a coal fly ash showed the sludge ash to have concentrations of copper, zinc, chromium and lead one or two orders of magnitude higher than coal fly ash.

No pesticide or PCB materials were found in the ash or scrubber water.

It was the opinion of the Office of Research and Monitoring solid waste representative on the Task Force that ash resulting from the incineration of sewage sludge would constitute no significant threat to the environment if ultimate disposal of the ash was by acceptable sanitary landfill practice as outlined by "Sanitary Landfill Design and Operation", a United States Environmental Protection Agency report.

Because of the importance which was given to the measured presence of various metals found in samples taken at South Lake Tahoe, Barstow, and Lorton, sludge samples were taken at additional sewage treatment plants, and analyzed for metals content. The added test sites were at Monterey, California, and at the Middlesex County, Joint Meeting, Passaic Valley, and Bergen County sewage treatment facilities in New Jersey. The New Jersey plants included units with significant industrial inputs.

Again, tests at the additional plants indicated the presence of biologically non-degradable metals. Quantitative results of these tests, however, were available only in raw data form when this report was written and are included as an appendix item. Based upon relationships developed during the comprehensive sampling program carried out at South Lake Tahoe, Barstow, and Lorton, it can be expected that quantities of certain heavy metals could be found in the incinerator effluent of the sludges analyzed from Monterey and the New Jersey plants.

The Monterey plant was also tested for stack effluents. Basic results were similar to those obtained from South Lake Tahoe, Barstow, and Lorton.

Section III
PLANT SURVEY AND SEWAGE SLUDGE INCINERATOR TEST PROGRAM

The Office of Air Programs undertook a survey and test program for sewage sludge incinerators in order to obtain information both for the setting of new source performance standards and, also, for the purposes of the EPA Task Force on Sewage Sludge Incineration. The following material provides basic information with regard to this program.

A. Background

The plant survey and test program of sewage sludge incinerators was undertaken for two purposes:

1. To survey a number of existing sludge incinerators selected from a list of installations supplied to the Office of Air Programs by the leading contractors who design and build incinerators. Based on a plant survey, a number of plants that demonstrated best emission control technology would be tested to obtain quantitative and qualitative analyses of emissions from these sources. This information in conjunction with other data would subsequently be used as a datum plane for the establishment of performance standards limiting the emissions to levels consistent with the current state of the art of control technology.

2. To satisfy the EPA Sludge Disposal Task Force requirements to identify time urgent problems in current and imminent sludge incineration activity. Since the use of incinerators as a means of disposing of sewage sludge is increasing, there is an urgent need to determine if this is a viable disposal method as far as its total environmental impact is concerned.

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To satisfy these two requirements an approach to establish a test program was planned in two phases.

Phase I involved inspection visits to sixteen existing incinerators that were reported to be capable of consistently meeting the most stringent particulate emission limitations (0.1 grains/scf). Based on this inspection survey, three plants which incinerate primarily residential sludge were selected for testing to provide preliminary data to the Environmental Protection Agency Sludge Incineration Task Force.

At each of the sixteen sites, samples were collected of the feed sludge, scrubber water inlet and outlet, and ash residue. The samples were sent to the Taft Water Research Center for analyses with particular emphasis on heavy metals.

Phase II was to consist of a minimum of three additional tests on plants selected after a more thorough review of existing incinerators and examinations of the analytical results of the Phase I study.

An additional fourteen incinerator sites were visited during Phase II. Only one of these plants, the N.W. Bergen plant at Waldwick, New Jersey, was deemed to be adequately controlled and suitable for testing. The State of New Jersey had tested this plant using the EPA test method. Particulate emissions measured during the State agency test ranged from 0.02 - 0.048 grains/cu. ft. (total catch).

B. Details

Source tests have been completed on four of the five incinerators selected for study. South Tahoe, California, was tested July 14-16,

Barstow, California on July 21-23, Fairfax County, Virginia on August 4-7, and Monterey, California on October 13-15, 1971. Samples of the sewage sludge residue (ash), and stack gas were collected and sent to the Ultimate Disposal Section, Office of Water Programs, Cincinnati, Ohio, for chemical analysis with particular emphasis on heavy metals.

The air samples were collected and analyzed by the source test contractor, York Research Corporation. The analysis was for NO_x and SO_2 concentrations and particulate grain loading. The results are reflected in the Test Data Summary, shown in Tables 2, 3, 4, 5 and 6.

All of the sewage treatment plants that have been source tested by the Office of Air Programs, have been plants that incinerate municipal or residential type sludge. To obtain data to aid the EPA Task Force in evaluating the environmental impact of sludge incinerators that burn a high percentage of industrial waste, a program was instituted by the OWP Ultimate Disposal Section. Sludge samples were collected from a number of plants that treat industrial waste and analyzed to determine composition and heavy metal content. Preliminary analyses of industrial type sludge indicates that the heavy metals found in industrial waste are basically the same as in residential waste, varying only in concentration. Using the sludge feed and stack emission analytical data collected from tests of residential type sludge incinerators, heavy metal concentrations in the stack gas of industrial sludge incinerators can be calculated when the concentration of a particular heavy metal in the sludge feed is known.

C. Conclusions

Based on the survey and tests of existing well-controlled municipal sewage sludge incinerators:

1. It has been adequately demonstrated that existing well-designed and operated municipal sewage sludge incinerators are capable of meeting the most stringent particulate emission control regulation existing in any State or local control agency.

2. Most incinerators that have been built in recent years are designed for greater throughputs than required for present municipality populations. Many operate either on a partial workweek, at reduced feed rates or both. Therefore, a practical air pollution emission standard for municipal sludge incinerators should be based on operation at less than 100 percent of design capacity.

TABLE 1

Sewage Sludge Incinerator Log

Plant	Location	
A	So. Lake Tahoe, California	Multiple Hearth (6) Herreshoff Incinerator. Design capacity 900 #/hr dry solids. Operated at 35% capacity during test. Control device W. W. Sly single cross flow perforated plate type impinjet scrubber. 6.0" H_2O pressure drop.
B	Barstow, California	Fluo-Solid (Fluidized Bed) Reactor. Design capacity 500 #/hr.dry solids. Operated at 95% capacity during test. Control device ARCO single cross flow perforated plate type impinjet scrubber. 4.0" H_2O pressure drop.
C	Fairfax County Lorton, Virginia	Two Multiple Hearth (7) Herreshoff Incinerators. Design capacity 2500 #/hr dry solids, each unit. Unit #1 which was tested, operated at about 50% of capacity during test. Control device Nichols Cyclonic Inertial jet scrubber 2.5" H_2O pressure drop.
D	Northwest Bergen County, Waldwick, N.J.	Fluo-Solid (Fluidized Bed) Reactor. Design capacity 1100 #/hr dry solids. Operated at 100% capacity during test. Control device; Peabody Five Plate impinjet scrubber. 20.0" H_2O pressure drop.
E	Monterey, California	Multiple Hearth (6) Herreshoff Incinerator. Design capacity 750 #/hr dry solids. Operated at 89% capacity during test. Control device; W. W. Sly single cross flow perforated plate type inpinjet scrubber. 6.0" H_2O pressure drop.

Table 2
Plant A

SUMMARY OF RESULTS

Run Number	1	2	3
Date	7-15-71	7-15-71	7-16-71
Stack Flow Rate-SCFM	1170	1300	1350
% CO_2 - Vol % dry	10.0	10.1	10.2
% Excess air @ test point	54.3	49.8	51.0
SO_2 Emission - ppm	13.64	14.28	13.63
SO_2 Emission - lbs/hr	.1596	.1856	.1840
NO_x Emission - ppm	271.63	82.81	67.48
HCl Emission - ppm	3.06	2.47	2.62
Particulate Emission - Filter			
Gr/CF @ stack conditions	0.0097	0.0474	0.0152
Gr/SCFD	0.0127	0.0616	0.0196
Lb/hr	0.127	0.686	0.227
	1.15#/ton	4.8#/ton	1.56#/ton
Particulate Emission - Total			
Gr/CF @stack conditions	0.0150	0.0532	0.0201
Gr/SCFD	0.0195	0.0692	0.0260
Lbs/hr	0.196	0.771	0.301
Process Conditions			
Sludge Feed to Furnace-lbs/hr dry solids	221.8	298.6	292.0

Table 3
Plant B

SUMMARY OF RESULTS

Run Number	1	2	3
Date	7-21-71	7-21-71	7-22-71
Stack Flow Rate-SCFM	1190	1170	1230
% CO_2 - Vol. % dry	8.8	9.9	9.1
% Excess Air @ Test point	38.7	50.7	59.4
SO_2 Emission-ppm	10.71	14.10	13.16
SO_2 Emission - lbs/hr	.1274	.1650	.1619
NO_x Emission - ppm	161.64	42.18	173.20
HCl Emission - ppm	1.64	2.78	2.15
Particulate Emission - Filter			
Gr/CF @ stack conditions	0.0468	0.0650	0.0464
Gr/SCFD	0.0551	0.0766	0.0545
Lbs/hr	0.562 2.2#/ton	0.768 3.24#/ton	0.574 2/84#/ton
Particulate Emission - Total			
Gr/CF @ stack conditions	0.0565	0.0729	0.0556
Gr/SCFD	0.0665	0.0859	0.0653
Lbs/hr	0.678	0.861	0.688
Process Conditions			
Sludge Feed to Furnace lbs/hr - dry solids	510.0	474.0	403.0

Table 4

Plant C

SUMMARY OF RESULTS

Run Number	1	2	3
Date	8-5-71	8-5-71	8-5-71
Stack Flow Rate-SCFM	9840	8510	10290
% CO_2 - Vol. % dry	4.2	4.3	2.2
% Excess Air @ test point	225	226	366
SO_2 Emission - ppm	1.97	2.02	1.98
NO_x Emission - ppm	62.9-46.2	83.5-76.0	44.4-54.8
HCl Emission - ppm	11.9	6.83	10.9
Particulate Emission - Filter			
Gr/CF @ stack conditions	0.0196	0.0099	0.0101
Gr/SCFD	0.0260	0.0136	0.0134
Lbs/hr	2.19 3.18#/ton	0.99 1.16#/ton	1.18 4.07#/ton
Particulate Emission - Total			
Gr/CF @ stack conditions	0.0252	0.0159	0.0128
Gr/SCFD	0.0335	0.0221	0.0170
Lbs/hr	2.83	1.61	1.5
Process Conditions			
Sludge Feed to Furnace lbs/hr - dry solids	1378	1710	580

Table 5

Plant D

SUMMARY OF RESULTS

Run Number	1	2	3
Date	5-3-71	5-4-71	5-4-71
Stack Flow Rate-SCFM	3650	3788	3513
% CO_2-Vol. % dry	4.0	5.1	4.0
% Excess Air @ test point			
Particulate Emissions - Filter			
Gr/CF @ stack conditions			
Gr/SCFD			
Lb/hr			
Particulate Emissions - Total			
Gr/CF @ stack conditions			
Gr/SCFD	0.020	0.031	0.048
Lb/hr	0.61	1.0	1.45
Process Conditions			
Sludge Feed to Furnace Lbs/hr - dry solids	650	650	650

Table 6

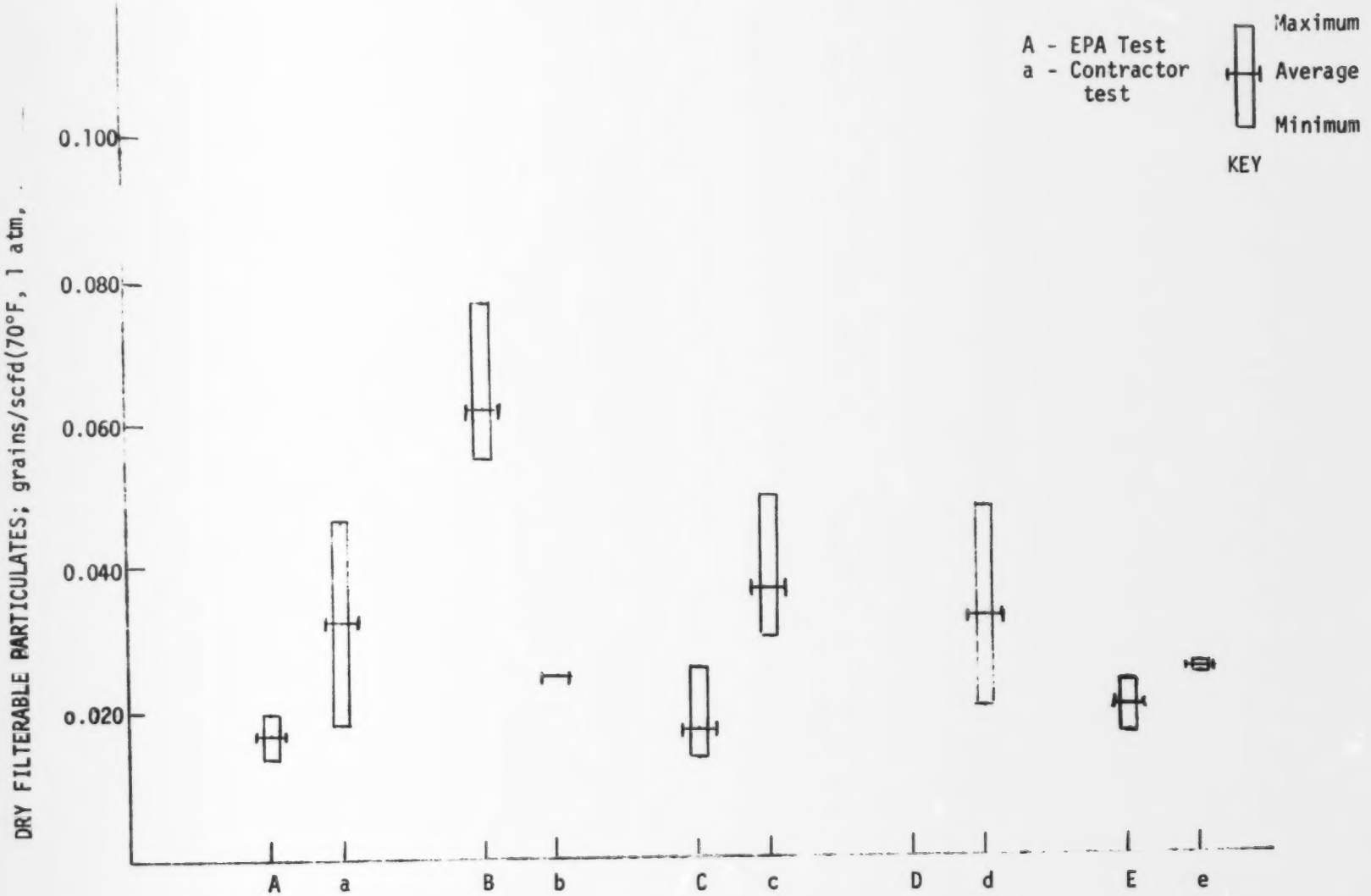
Plant E

SUMMARY OF RESULTS

Run Number	1	2	3
Date	10-31-71	10-14-71	10-14-71
Stack Flow Rate - SCFM	3310	2950	2120
$\%CO_2$ - Vol. Dry	3.8	4.7	2.7
% Excess air @ Test Point	469.2	183.6	268.8
SO_2 Emission - PPM	2.23	2.51	3.22
NO_x Emission - PPM	35.39	19.45	11.47
HCl Emission - PPM	.624	1.33	.621
Particulate Emission - Filter			
Gr/CF @ stack conditions	.0187	.0155	.0132
Gr/SCFD	.024	.020	.017
Lb/Hr.	.680	.505	.309
Particulate Emission - Total			
Gr/CF @ stack conditions	.0289	.0287	.0348
Gr/SCFD	.037	.037	.045
Lb/Hr	1.049	.935	.818

FIGURE 1

PARTICULATE EMISSIONS FROM SLUDGE INCINERATORS



Section IV

THE EFFECT OF INCINERATION ON METALS, PESTICIDES AND POLYCHLORINATED BIPHENYLS PRESENT IN SEWAGE SLUDGE

The Office of Research and Monitoring accepted the responsibility for detailed analyses of the material obtained during the sampling program discussed in Chapter II. The following material reports on these analyses.

A. Conclusions and Recommendations

Concentration of pesticides and PCB's in sludge are occasionally quite high. They may be hazardous if sludge is carelessly discarded in the environment. Incineration very likely destroys these materials, but positive evidence is lacking.

It is recommended that:

1. More data be collected on sludges. A regular analysis program should be instituted at a few plants.
2. Means be developed for determining trace amounts of chemicals in incinerator off-gases.
3. Advice should be obtained on the hazards of the concentrations of pesticides and PCB's encountered in sludge.
4. Experiments should be carried out which clearly demonstrate the fate of pesticides and PCB's upon incineration.
5. Analytical methods development for potential hazardous chemicals in sludge should be accelerated.

Some metals appear in the ash in lower proportion than they appear in the sludge (fixed-solids basis), and they are higher in the stack gas particulates. All of the mercury in the sludge apparently is lost in the stack gases. The residue from burning sludge is higher in certain potentially hazardous metals than the residues of fly ash from burning of coal. These metals originate in both industrial and domestic wastes.

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It is recommended that:

1. More particulate sampling and analysis be carried out to establish a reasonably accurate way for predicting the composition of stack-gas particulates from a knowledge of the sludge composition.

2. Particulate sampling methods be improved.

3. Long-term tests be carried out on a versatile pilot-scale incinerator to accurately determine the material flows and compositions.

4. Communities analyze their sludges and sewage for metals on a regular basis so that high concentrations, which would appear in proportionate mass in the fly ash from incineration, would be detected.

B. Introduction

One of the tasks taken on by the Taft Water Research Center representatives to the Sludge Incineration Task Force was to provide analytical information as needed for incinerator tests being conducted by the Air Pollution Division of Compliance. Samples of sludges and incinerator ash were sent by Air Pollution staff from numerous potential incinerator test sites, to be analyzed by emission spectroscopy for a variety of metals. During the actual tests at incinerator sites, central coordination of analytical work was provided with analytical tests being conducted at the Advanced Waste Treatment Laboratory and the Analytical Quality Control Laboratory of the Taft Water Research Center, and at North Carolina State University (coordinated through the Office of Air Program's Source and Emission Testing Division). The data obtained for the incinerator tests is insufficient to draw broad conclusions on the contents of sludges. It has been supplemented by data collected on sludges from locations with widely differing populations and industrial mix.

C. Results and Discussion

General Experimental Plan

The incinerator testing was limited to two incinerator types: the multiple-hearth incinerator, and the fluidized bed incinerator. These incinerators are represented schematically in Figure 1. With respect to process flows, the most significant difference is that the major part of the ash leaves from the bottom of the multiple hearth furnace, whereas in the fluidized bed incinerator, all the ash is carried overhead and is removed from the bottom of the scrubber.

The tests at the various sites followed methods developed previously by the Office of Air Programs for air pollution source testing. Standard methods for particulate sampling and gas sampling were followed. These procedures were designed for determining particulate loading and for analysis of the commonly encountered gaseous pollutants. The analytical work was designed to collect as much additional useful data as possible in order to optimize the information obtained from the testing program.

Sludge, ash, scrubber water in, scrubber water out, and particulates carried overhead were analyzed for metals. Except for the particulates, these same streams were analyzed for pesticides and PCB's. The tests on each incinerator were divided into three six-hour testing periods. Within the limitations of manpower available at the test site, samples were taken in as representative a fashion as possible. Tests were run on a multiple hearth incinerator at South Lake Tahoe, California, a fluidized bed incinerator at Barstow, California, and at another multiple hearth unit at Lorton, Virginia.

Pesticides and PCB's

The intent of the study of pesticides and PCB's was to determine their levels in sludge, and to determine what happens to them during incineration.

Data are presented in Table 7 which indicate the levels of pesticides which can be found in a random selection of sludges. The data are summarized below:

Compound	Range (ppm)
Aldrin	16 (in one sludge only)
Dieldrin	0.08 to 2.0
Chlordane	3.0 to 32
DDD	not detected to 0.5
DDT	not detected to 1.1
PCB's	not detected to 105

The wide range of concentrations indicate that pesticides and PCB's could be a minor problem in some cases, and severe in others. It is not likely that there will be an easy way to judge "a priori" where a problem will exist.

Pesticide and PCB determinations were made on sludges collected during the incinerator tests at Lorton, Barstow, and Tahoe. These data are also presented in Table 7 PCB's were found in all of these sludges, but concentrations were low (1.2 to 2.5 ppm). Barstow showed an unusually high concentration of chlordane. Pesticides were not determined for the Tahoe sludges.

A major gap in our study is the lack of analyses of pesticides and PCB's in the gas stream. Since the pesticides (and even some varieties of the PCB's) have a significant vapor pressure at room temperature. they may not be captured in the particulate sampler.

Pesticides and PCB's were found only in the sludge. They were not found in the ash from either type incinerator, nor in the inlet or outlet scrubber water. Ash can be analyzed for these materials to the same degree of sensitivity as in sludge. A level of 0.1 microgram/g(ppm) could have easily been detected. It is quite certain that these materials are not being carried out in the ash.

The mass flow rate of water to the scrubber is about 400 times the dry solids flow rate to the incinerator. Consequently, the concentration at which these materials can be detected in water must be sufficiently low to be sure that they are not escaping in the scrubber water. Fortunately, analytical techniques are such that these materials can be detected in water to the nearest 0.1 nanogram/g (ppb). Consequently, it is reasonable to believe that they are not in the scrubber water. The possibility that low concentrations of PCB's could be adsorbed by the ash or the walls of the sample container do not allow us to be absolutely certain of this statement.

Since the PCB's do not appear in ash or scrubber water, they are either destroyed by incineration or remain as vapors in the water-scrubbed (and cooled) gas stream. Since all of these materials have some solubility in water, it is unlikely that no trace would be present in the scrubber water. Consequently, their escape as vapors from the incinerators seems unlikely.

It is suggested that the pesticides and PCB's are destroyed by incineration. Eventually, direct experimental evidence that this is the case should be obtained.

Metals

The intent of the study of metals was to determine their levels in sludge, in ash, and in the particulates entrained in the gas stream leaving the incinerator.

Concentrations of metals in sludges are shown in Table 8. It is clearly difficult to predict the composition of a sludge. Lake Tahoe sewage is largely domestic, yet its cadmium level is higher than three of the plants with a much higher proportion of industrial waste. Dayton and Mill Creek (Cincinnati) have a high proportion of industrial waste; however, except for aluminum, the Dayton sludge is much higher in metals than the Mill Creek sludge.

The metal concentration in sludge ash can be estimated from the sludge analysis. Except for mercury (see below), metals remain in the ash or the fly ash If the sludge is about 25% fixed solids after ignition, this ash will have approximately four times the concentration of metals as did the dried sludge. A comparison of sludge ash composition with a coal fly ash shows the sludge ash to have concentrations of copper, zinc, chromium, and lead one or two orders of magnitude higher than coal fly ash.

The tests in the incinerators at Tahoe, Barstow, and Lorton revealed that the ratio of a metal to fixed solids in the sludge was not always the same as its concentration in the ash. This indicates that some disproportionation (or classification) was occurring. For example, if the ash stream showed a lower concentration of a metal than its concentration in the sludge on a fixed solids basis, this indicates that the particulates (or fly ash) should have a higher concentration of the metal than either sludge or ash.

A comparison of metal content of the sludge (fixed-solids basis) with the metal content of the ash is shown in Table 9 for the three incinerators tested. The data show that all of the mercury is classified into the combustion gas stream, probably as mercury vapor or as a volatile mercury compound. The evidence is strong that lead compounds are being classified into the fly ash stream and carried off by the combustion gases. Silver, barium, chromium, and copper may show a similar effect, but more substantiating data are needed.

This result indicates that for some metals it is not adequate to estimate the composition of the fly ash stream from a knowledge of the sludge analysis. The analysis of the particulates which leave the incinerator stack is of primary importance. Analyses were made on the particulate samples collected at Tahoe, Barstow, and Lorton. These data are shown in Table 10. The particulate analyses are presented as well as the ratio of metal concentration in the particulates to the metal concentration in the sludge (fixed-solids basis). The three 6-hour particulate samples were analyzed for Tahoe and Barstow, but only one sample was available for Lorton.

The data in Table 10 show reasonable agreement between samples, but the agreement is not good enough to establish any precise quantitative relationships. Sample size was too small to permit anything but the emission spectrograph analysis, so no results were obtained for mercury, selenium, and antimony. It is presumed with a fair degree of certainty that no mercury is present in the particulates.

The ratio of metal concentrations in particulates to the concentration in sludge shows consistently high value for zinc. This is unexpected from the ash results discussed above and is in fact due to gross zinc contamination from the glass fiber filter used to collect particulates. The ratio for lead is high for the two multiple hearth incinerators but not for the fluidized bed incinerator (Barstow). This could be a real affect caused by differences in the two types of furnace. The loss of lead from the Barstow ash was so pronounced (see Table 9 that this low level in the Barstow particulates leads one to speculate that somehow a portion of the lead in the stack gas sample is not being deposited in the particulate sampler.

The investigation of particulate composition indicates that except for mercury and possibly lead, the off-gas stream and the particulates will not be enriched in metals over the amount indicated by concentration in the sludge (fixed-solids basis). More definitive data are clearly desired. Longer-term testing at an incinerator site would be desired. Particulate sampling should be improved to give larger samples free of contaminants. A pilot plant study of emissions from incineration, where all stream flows could be rigidly controlled and metal concentrations of feed set at desired levels, would be of great value.

Table 7

PESTICIDE AND PCB CONTENT OF SLUDGES
(micrograms/gram dry solids)*

Sludge Source	Aldrin	Dieldrin	Chlordane	DDD	DDT	PCB
						(Arochlor 1254)
Mt. Washington Activ. 5/19/71	16.2	0.6	32.2	n.d.	1.1	n.d.
Shayler Run Activ. 3/20/71						
Sample 1	n.d.	1.3	18.2	0.5	0.2	3.2
Sample 2	n.d.	1.4	18.6	0.5	0.2	3.2
Lebanon Digest. 6/3/71						
Sample 1	n.d.	0.3	9.8	0.3	0.2	2.5
Sample 2	n.d.	0.2	9.1	0.3	0.05	2.5
Barstow, Composite of Three Samples 7/21/71		2.0	26.5	0.2	n.d.	1.4
Lorton, Composite of Three Samples 8/5/71		0.08	3.0	0.1	n.d.	1.2
Tahoe, Composite of Six Samples 7/15/71						2.5
Mill Creek Digest. 8/20/71						12.7
Little Miami Digest. 8/20/71						32.0
Dayton Digest. 8/25/71						105.0
Indianapolis Digest. 8/27/71						
Sludge 1						4.0
Filter Cake						3.3

* Date reported in this table were obtained by H. Boyle and C. Mashni, Advanced Waste Treatment Research Laboratory, National Environmental Research Center, Cincinnati, Ohio.

Table 8

CONCENTRATION OF METALS IN SLUDGES
(mg/g)

	Tahoe	Dayton	Little Miami Cincinnati	Mill Creek Cincinnati	Lorton Va.	Indianapolis Plant 1	Barstow
	7/15/71	8/25/71	8/20/71	8/20/71	8/5/71	8/23/71	7/20/71
Ag, Silver	0.27	0.36	0.03	n.d.	n.d.	n.d.	0.05
Al, Aluminum	13.2	12.5	8.8	32.2	4.4	5.2	16.2
Ba, Barium	3.0	3.0	0.7	n.d.	0.7	1.3	1.5
Be, Beryllium	n.d.[1]	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Cd, Cadmium	0.18	0.8	n.d.	n.d.	0.17	0.24	0.58
Co, Cobalt	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Cr, Chromium	1.0	5.9	1.7	1.8	0.4	2.6	0.5
Cu, Copper	1.3	6.0	2.3	1.6	0.9	2.0	1.7
Fe, Iron	8.7	20.4	16.0	13.2	27.4	15.3	10.6
Hg, Mercury	4.5*	n.a.[2]	n.a.	n.a.	3.0*	n.a.	5.5*
Mn, Manganese	0.6	1.1	1.2	0.6	0.5	0.6	0.18
Ni, Nickel	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Pb, Lead	2.8	6.9	2.0	2.7	1.1	2.8	0.8
Sr, Strontium	0.51	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
V, Vanadium	n.d.	n.d.	n.d.	1.6	n.d.	n.d.	2.1
Zn, Zinc	1.6	8.4	7.8	4.7	0.4	1.2	1.4

* - micrograms/g
1 - n.d.: not detected
2 - n.a.: not analyzed

Analytical determinations on these sludges were carried out by J. Kopp, Analytical Quality Control Laboratory, Robert A. Taft Water Research Center.

Table 9

METAL TO FIXED SOLID RATIO FOR
SLUDGE AND ASH FOR INCINERATOR TEST SITES (mg/g)

Element	Lake Tahoe, Calif.		Barstow, Calif.		Lorton, Va.	
	Sludge	Ash.	Sludge	Ash	Sludge	Ash
Ag, Silver	0.6	i.d.[1]	0.14	0.05	0.15	0.05
Al, Aluminum	27.	24.	16.	16.	8.1	16.
Ba, Barium	6.0	1.1	4.1	1.5	1.2	0.9
Be, Beryllium	n.d.[3]	n.d.	n.d.	n.d.	n.d.	n.d.
Ca, Calcium	62.	290.	46.	73.		235.
Cd, Cadmium	0.37	0.20	n.d.	0.58	0.31	0.22
Co, Cobalt		0.2	n.d.	n.d.	n.d.	n.d.
Cr, Chromium	2.0	0.3	2.9	0.5	0.7	0.6
Cu, Copper	2.6	1.3	2.5	1.7	1.6	1.6
Fe, Iron	18.	8.9	12.	11.	50.	43.
Hg, Mercury	9.0*	n.d.	20.*	n.d.	6.*	n.d.
K, Potassium	1.4	1.3	3.3		1.8	2.3
Mg, Magnesium	12.1	16.2	2.8		7.0	6.6
Mn, Manganese	1.1	0.5	0.18	0.18	0.9	0.9
Na, Sodium	1.8	1.8			1.1	1.4
Ni, Nickel	[2]	i.d.	n.d.	n.d.	n.d.	n.d.
P, Phosphorus	81.	84.			45.	57.
Pb, Lead	5.8	0.7	7.0	0.85	2.0	1.0
Sb, Antimony	1.3*	1.3*				
Se, Selenium	12.3*	12.3*				
Sr, Strontium	1.0	0.7	n.d.	n.d.	n.d.	n.d.
V , Vanadium	n.d.	0.4	n.d.	2.1	n.d.	n.d.
Zn, Zinc	1.6	1.6	2.4	1.4	0.8	0.7

(1) i.d. - insufficient data
(2) blank - not determined
(3) n.d. - not detected
* micrograms/gram

Data on most elements were determined by emission spectrograph by J. Kopp, Analytical Quality Control Laboratory. As, Sb, and Se were determined by neutron activation analysis at North Carolina State University (coordinated by D. von Lehmden, Analytical Branch, Division of Air Programs).

Table 10

CONCENTRATION OF METALS IN PARTICULATES (mg/g)

Location / Sample	South Lake Tahoe 1	2	3	R[1]	Barstow 1	2	3	R	Lorton 1	R
Elements										
Ag, Silver	0.2	n.a.[2]		0.4	0.05	n.a.	n.a.	0.4	n.a.	n.s.i.[4]
As, Arsenic	<0.5	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	n.a.	n.s.i.
Be, Beryllium	1.0[3]	0.5[3]	0.5[3]	n.s.i.	0.5[3]	0.5[3]	0.5[3]	n.s.i.	<0.5[3]	n.s.i.
Cd, Cadmium	1.0	1.0	1.5	2.6	0.1	0.08	0.1	n.s.i.	<0.25	<0.8
Co, Cobalt	4.0	0.05	0.3	n.s.i.	n.i.[5]	0.4	0.05	n.s.i.	0.05	n.s.i.
Cr, Chromium	1.0	0.1	0.4	0.2	0.5	0.4	0.6	0.2	0.5	0.7
Cu, Copper	1.0	0.04	0.8	0.3	2.0	1.8	2.5	0.7	1.3	0.8
Fe, Iron	4.0	28.	11.	0.6	5.0	12.	16.	1.0	17.	0.3
Mn, Manganese	0.5	0.4	0.3	0.4	0.1	0.1	0.2	0.6	0.4	0.5
Ni, Nickel	0.4	0.2	0.3	n.s.i.	<0.1	0.05	0.1	n.s.i.	2.0	n.s.i.
Pb, Lead	20.	7.	15.	2.6	1.0	0.3	0.9	0.1	9.0	4.5
Sr, Strontium	0.4	n.a.	n.a.	<0.4	0.2	n.a.	n.a.	n.s.i.	n.a.	n.i.
V, Vanadium	<0.2	<0.05	<0.05	n.s.i.	<0.1	<0.05	0.1	n.s.i.	<0.05	n.s.i.
Zn, Zinc	40.	50.	55.	30.	2.5	8.	12.	36.	19.	24.

1 R is ratio of metal concentration in particulates to concentration in the sludge. Median particulate concentration used in the calculation.

2 n.a. means "not analyzed"

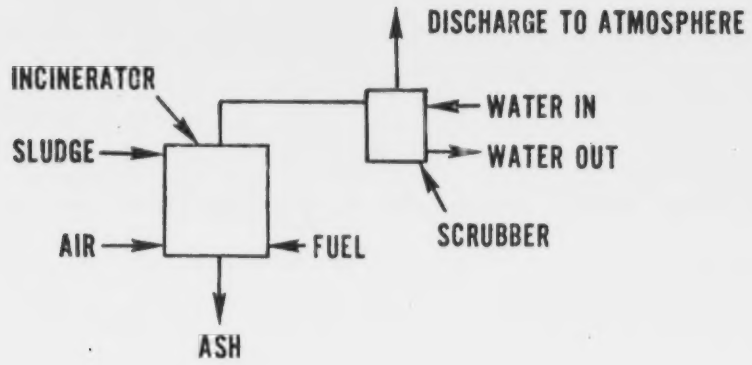
3 Beryllium concentration is given in micrograms per gram

4 n.s.i. means "not sufficient information"

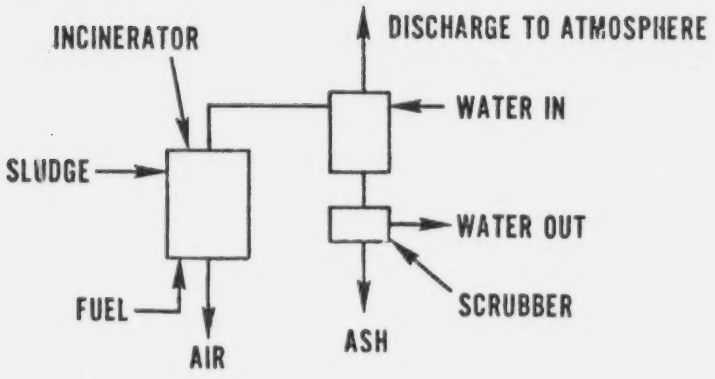
5. n.i. means "no information"

FIGURE 2

SCHEMATIC REPRESENTATION OF INCINERATOR TYPES



(1a) Multiple Hearth Incinerator



(1b) Fluidized Bed Incinerator

Section V

JUSTIFICATION OF INCINERATOR DESIGN CRITERIA FOR PCB AND PESTICIDE DESTRUCTION

Studies of the thermal decomposition of pesticides and PCB's in sewage sludge incineration have not been conducted to date. Instead, research has been directed toward incinerators designed strictly for the combustive destruction of concentrated amounts of waste PCB's and pesticides. Multiple hearth, fluidized bed, and rotary kiln incinerators have been employed in this context. In addition, some information is also being generated through studies of the regeneration of activated carbon used to remove chlorophenolic wastes from solution.

While the intent of current incineration work is not in terms of sludge incineration, it is felt that the information generated may be applicable to the decomposition of PCB's and pesticides in sewage sludge incinerators. Rapid thermal degradation of most pesticides has been shown to begin at approximately 500°C with near total destruction at 900°C, (1652°F [1,2]. In many instances, however, these materials volatilize before burning, thus forcing the use of afterburners on incinerators to provide complete destruction. The Rhodia-Chipman Chemical Company achieves near total destruction of pesticides in its multiple hearth carbon regenerator by providing an afterburner using a 0.23 - 0.80 second retention time at 1600 - 1800°F [3]. Similar figures were generated in a University of Texas at Austin study where 1400 - 1800°F at 0.30 - 0.50 seconds was required for thermal destruction.[4]

The PCB's are even more thermally stable than most pesticides, as one would suspect. The primary manufacturer of these materials, Monsanto Chemical Company, offers an incineration service to customers for disposing

Section VI

REFERENCES

1. Basic Research on Equipment and Methods for Decontamination and Disposal of Pesticides and Pesticide Containers, Annual Report (June 1968 - June 1969), U.S.D.A. Grant Number, 12-14-100-9182 (34), Mississippi State University.

2. Organic Pesticides and Pesticide Containers--A Study of Their Decontamination and Combustion, Final Report (1970), Bureau of Solid Waste Management Contract Number CPA-69-140, Foster D. Snell, Inc.

3. Personal Conversation, January 19, 1972, Mr. Thomas Henshaw, Rhodia-Chipman Chemical Company, Portland, Oregon.

4. The Pesticide Manufacturing Industry - Current Waste Treatment and Disposal Practices, Project Number 12020 FYE-01/72, University of Texas at Austin.

5. Personal Conversation, January 20, 1972, Mr. Arthur Pier, Monsanto Chemical Company, St. Louis, Missouri.

of waste PCB's. The incinerator at St. Louis, Missouri achieves total destruction of concentrated PCB's at 2400°F with a retention time of 2.5 seconds.[5/] Experiments have shown, however, that 99% destruction is possible at 1600 - 1800°F in 2.0 seconds.[5/]

SECTION VII

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APPENDIX A

TABLE: CONCENTRATIONS OF METALS IN SLUDGES

(Mg/g)

Monterey, California 10/13/71	Middlesex County New Jersey 10/27/71	Joint Meet. N. J. 10/25/71	Passaic Valley N. J. 11/1/71	Bergen Co. N.J. 10/26/71
0.03	N. D.	0.08	N. D.	0.08
2.40	3.00	5.20	3.40	12.6
0.76	0.38	1.42	0.48	1.20
N. D.	N. D.	N. D.	N. D.	N. D.
0.70	0.70	1.30	0.90	1.46
N. D.	N. D.	N. D.	N. D.	N. D.
0.26	N. D.	0.34	0.20	0.40
N. D.	N. D.	1.80	0.86	7.60
0.60	0.60	2.50	0.62	1.52
2.60	4.20	10.4	2.40	11.8
A. P.	A. P.	A. P.	A. P.	A. P.
0.07	N. D.	0.80	0.32	9.40
N. D.	N. D.	N. D.	N. D.	N. D.
0.22	N. D.	0.38	0.32	0.38
0.60	N. D.	0.80	1.60	1.70
7.20	7.00	15.6	7.60	34.2
N. D.	N. D.	N. D.	N. D.	N. D.
N. D.	N. D.	0.26	N. D.	0.28
1.95	1.90	2.20	2.20	2.80

). Not Detected.

). Analysis Pending.

APPENDIX B

NORTH CAROLINA STATE UNIVERSITY | AT RALEIGH

DEPARTMENT OF NUCLEAR ENGINEERING

NUCLEAR ENERGY SERVICES
ENGINEERING AND EXPERIMENTATION DIVISION
BOX 5636 ZIP 27607

September 27, 1971

Mr. Darryl von Lehmden
Environmental Protection Agency
Source and Emission Testing Division
Research Triangle Park, North Carolina Report #2679A-B

Dear Mr. von Lehmden:

Enclosed are the results of the neutron activation of sludge incinerator samples for the South Lake Tahoe facility which have been analyzed for Se and Sb content. Table 1 shows the values found.

Table 1

South Lake Tahoe Sludge Incinerator

Sample Description	Sb Content	Se Content
#71 Scrubber H_2O Inlet 3:30 p.m. 7-15-71	< 0.01 ug/ml	< 0.03 ug/ml
#72 Scrubber H_2O Inlet 7:45 p.m. 7-15-71	< 0.01 ug/ml	< 0.03 ug/ml
#73 Scrubber H_2O Inlet 9:45 a.m. 7-16-71	< 0.01 ug/ml	< 0.03 ug/ml
#74 Scrubber H_2O Outlet 4:00 p.m.7-15-71	< 0.01 ug/ml	< 0.17 ug/ml
#75 Scrubber H_2O Outlet 7:20 p.m. 7-15-71	0.02 ug/ml	0.22 ug/ml
#76 Scrubber H_2O Outlet 9:50 p.m. 7-16-71	< 0.01 ug/ml	< 0.08 ug/ml
#77 Sludge Cake 3:45 p.m. 7-15-71	0.66 ppm	8.49 ppm
#78 Sludge Cake 4:45 p.m. 7-15-71	1.01 ppm	6.05 ppm
#79 Sludge Cake 7:20 p.m. 7-15-71	0.36 ppm	< 6.00 ppm
#80 Sludge Cake 7:50 p.m. 7-15-71	0.75 ppm	6.14 ppm
#81 Sludge Cake 9:40 a.m. 7-16-71	0.72 ppm	3.46 ppm
#82 Sludge Cake 10:20 a.m. 7-16-71	0.19 ppm	< 6.00 ppm
#83 Incinerator Ash 4:00 p.m. 7-15-71	< 0.20 ppm	7.45 ppm
#84 Incinerator Ash 7:35 p.m. 7-15-71	1.15 ppm	22.99 ppm
#85 Incinerator Ash 7-16-71	1.17 ppm	6.59 ppm

Experimental Parameters:

Sample size: 1/3 gram and 1/2 ml
Irradiation time: 4 hours
Flux: 3×10^{13} n/cm^2 sec.
Decay time: Approx. 7 days

SEP 29 1971

THE UNIVERSITY OF NORTH CAROLINA, William Friday, President, comprises: *North Carolina State University at Raleigh, the University of North Carolina at Chapel Hill, the University of North Carolina at Greensboro, the University of North Carolina at Charlotte, the University of North Carolina at Asheville, and the University of North Carolina at Wilmington.*

Detection system: Ortec 10 mm Low Energy Photon Detector coupled to a RIDL 400 channel analyzer.

If you have any questions about this report, please call (919) 755-2323.

Sincerely,

Jack Weaver

Jack Weaver
NAA and Isotope Specialist

JW:lpe

APPENDIX C

NORTH CAROLINA STATE UNIVERSITY | AT RALEIGH

DEPARTMENT OF NUCLEAR ENGINEERING

NUCLEAR ENERGY SERVICES
ENGINEERING AND EXPERIMENTATION DIVISION
BOX 5636 ZIP 27607

September 28, 1971

Mr. Darryl von Lehmden
Environmental Protection Agency
Source and Emission Testing Division
Research Triangle Park, North Carolina 27711 Report #2679-D

Dear Mr. von Lehmden:

Enclosed are the results of the neutron activation analysis for Hg in sludge incinerator samples from Barstow, California and Fairfax, Virginia. Table 1 and 2 show the results respectively.

TABLE #1

Barstow, Calif. Sludge Incinerator
Mercury Content

Sample Description	Antimony	Selenium
EPA #86 Scrubber Inlet - Test 1	< 0.01 ug/ml	< 0.03 ug/ml
EPA #87 Scrubber Outlet - Test 1	< 0.01 ug/ml	0.11 ug/ml
EPA #88 Scrubber Inlet - Test 2	< 0.01 ug/ml	< 0.03 ug/ml
EPA #89 Scrubber Outlet - Test 2	< 0.01 ug/ml	< 0.03 ug/ml
EPA #90 Scrubber Inlet - Test 3	< 0.01 ug/ml	< 0.03 ug/ml
EPA #91 Scrubber Outlet - Test 3	< 0.01 ug/ml	< 0.03 ug/ml
EPA #92 Sludge - Test 1	4.87 ppm	10.66 ppm
EPA #93 Sludge - Test 2	2.48 ppm	6.94 ppm
EPA #94 Sludge - Test 3	2.60 ppm	9.21 ppm

TABLE #2

Fairfax County, Virginia
Sludge Incinerator

Sample Description	Antimony	Selenium
EPA #95 Incoming Sludge	< 0.32 ppm	< 2.92 ppm
EPA #96 Filtered Sludge	1.61 ppm	< 2.92 ppm
EPA #97 Incinerator Ash	< 0.14 ppm	< 4.39 ppm

THE UNIVERSITY OF NORTH CAROLINA, William Friday, President, comprises: *North Carolina State University at Raleigh, the University of North Carolina at Chapel Hill, the University of North Carolina at Greensboro, the University of North Carolina at Charlotte, the University of North Carolina at Asheville, and the University of North Carolina at Wilmington.*

Experimental Parameters:

Sample size: 1/3 gram and 0.3 ml
Irradiation time: 4 hours
Flux: 3×10^{13} n /cm^2 sec.
Decay time: Approx. 4 days
Detection procedures: Instrumental NAA using a 10 mm Ortec Low Energy Photon Detector coupled to a RIDL 400 channel analyzer.
Data evaluation: Quantitative analysis was performed using the 80.25 KeV photopeak of Hg-197.

If you have any questions concerning this report, please call (919) 755-2323.

Sincerely,

Jack Weaver

Jack Weaver
NAA and Isotope Specialist

JW:lpe

APPENDIX D

NORTH CAROLINA STATE UNIVERSITY | AT RALEIGH

DEPARTMENT OF NUCLEAR ENGINEERING

NUCLEAR ENERGY SERVICES
ENGINEERING AND EXPERIMENTATION DIVISION
BOX 5636 ZIP 27607

October 4, 1971

Mr. Darryl von Lehmden
Environmental Protection Agency
Source and Emission Testing Division
Research Triangle Park, North Carolina

Report #26794-E

Dear Mr. von Lehmden:

Enclosed are the results of the neutron activation of sludge incinerator samples analyzed for arsenic content. Tables 1, 2 and 3 show the values found.

Table 1

South Lake Tahoe Sludge Incinerator

Sample Description	Arsenic Content
#71 Scrubber H_2O Inlet 3:30 p.m. 7/15/71	<0.05 ug/ml
#72 Scrubber H_2O Inlet 7:45 p.m. 7/15/71	<0.05 ug/ml
#73 Scrubber H_2O Inlet 9:45 a.m. 7/16/71	<0.05 ug/ml
#74 Scrubber H_2O Outlet 4:00 p.m. 7/15/71	<0.05 ug/ml
#75 Scrubber H_2O Outlet 7:20 p.m. 7/15/71	<0.05 ug/ml
#76 Scrubber H_2O Outlet 9:50 p.m. 7/16/71	<0.05 ug/ml
#77 Sludge Cake 3:45 p.m. 7/15/71	21.69 ppm
#78 Sludge Cake 4:45 P.m. 7/15/71	40.64 ppm
#79 Sludge Cake 7:20 p.m. 7/15/71	21.67 ppm
#80 Sludge Cake 7:50 p.m. 7/15/71	27.82 ppm
#81 Sludge Cake 9:40 a.m. 7/16/71	21.52 ppm
#82 Sludge Cake 10:20 a.m. 7/16/71	15.65 ppm
#83 Incinerator Ash 4:00 p.m. 7/15/71	27.48 ppm
#84 Incinerator Ash 7:35 p.m. 7/15/71	25.47 ppm
#85 Incinerator Ash 7/16/71	23.50 ppm

Table 2

Barstow, California Sludge Incinerator

EPA #86 Scrubber Inlet - Test 1	<0.05 ug/ml
EPA #87 Scrubber Outlet - Test 1	0.40 ug/ml
EPA #88 Scrubber Inlet - Test 2	<0.05 ug/ml
EPA #89 Scrubber Outlet - Test 2	0.79 ug/ml
EPA #90 Scrubber Inlet - Test 3	<0.05 ug/ml
EPA #91 Scrubber Outlet - Test 3	0.31 ug/ml
EPA #92 Sludge - Test 1	15.27 ppm
EPA #93 Sludge - Test 2	8.51 ppm
EPA #94 Sludge - Test 3	6.59 ppm

THE UNIVERSITY OF NORTH CAROLINA, William Friday, President, comprises: North Carolina State University at Raleigh, the University of North Carolina at Chapel Hill, the University of North Carolina at Greensboro, the University of North Carolina at Charlotte, the University of North Carolina at Asheville, and the University of North Carolina at Wilmington.

Table 3

Fairfax County, Virginia Sludge Incinerator

Sample Description	Arsenic Content
EPA #95 Incoming Sludge	41.26 ppm
EPA #96 Filtered Sludge	55.56 ppm
EPA #97 Incinerator Ash	17.68 ppm

Experimental

Sample size: Approximately ¼ gram and ½ ml
Irradiation Time: 3 hours
Flux: 2×10 "n/cm^2- sec
Decay Time: 36 hours
Detection System: 10 minute count on GE (li) coupled to an RIDL 900 channel analyzer.

If you have any questions, please call me at 919-755-3347.

Sincerely,

Jack Weaver

Jack Weaver
NAA and Isotope Specialist

JW/lrt

APPENDIX E

PRELIMINARY REPORT

THE IMPACT OF SLUDGE INCINERATION ON AIR AND LAND

by

B. V. SALOTTO

J. B. FARRELL

Prepared for EPA Task Force on Sludge Incineration

July 12, 1971

THE IMPACT OF SLUDGE INCINERATION ON AIR AND LAND

As more or larger sewage treatment plants go on stream, the quantities of sludge to be disposed of will increase in the coming years. Incineration of sludge will receive more attention as a method of disposal particularly if future regulations make ocean disposal more expensive or prohibitive. Before a true assessment of the impact of sludge incineration can be made, it is necessary to have as much information as possible on the characteristics and production of sewage sludges to be incinerated. This report is a preliminary document which provides information on the components of sludge and the effects these may have on air and land if incineration is used. It has been prepared without an in-depth review of the literature and should not be considered the state-of-the-art.

I. Material Removed by Sewage Treatment

Primary treatment settles out most of the suspended solid material in sewage as primary sludge, which is 65 to 75 percent combustible. The ash contains stable inorganic constituents. Primary effluent contains soluble organic and inorganic materials plus some suspended solids. Purpose of secondary treatment is to oxidize soluble organics by action of microorganisms. In the process, the mass of microorganisms increases and a portion must be wasted, generally as a dilute sludge. Final effluent from the clarifier contains from 2 to 15 percent of the original BOD or COD of the waste stream. Major dissolved inorganic ions are NH_4, Ca, Mg, Na, K, SO_4, HCO_3 and Cl.

Nutrients such as nitrogen and phosphorus are partly removed by the sludge produced by the treatment process. The degree of removal is never uniform. Information on suspended solids, COD, nitrogen and phosphorus removals occurring

in conventional treatment has been culled from various sources[1,2,3,4] and is listed in Table I.

The fate of heavy metals such as copper, chromium, nickel, and zinc through sewage treatment process has been reported[5]. Four plants were selected where the receipt of these metals was thought to be high. Incoming and outcoming concentrations of these metals are shown for the four municipal plants in Table II. The receipt of these metals did not significantly affect the treatment efficiency, but it is interesting to note that the sludges captured and immobilized appreciable amounts especially of chromium and zinc.

II. Quantities and Major Components of Sludge

Sewage sludge is a brown to blackish, amorphous, heterogeneous, non-newtonian liquid containing dissolved, colloidal, and suspended solids. Its physical, chemical, and microbiological characteristics are largely dependent on source of waste, type of treatment producing the sludge, and subsequent sludge treatment. Depending on its origin, sludge is designated as primary, waste activated or filter humus. It is called "raw" sludge unless it has been stabilized by processes such as digestion or heat treatment. Water content ranges from about 85 to 99.9 percent. It contains humus-like organic material, nitrogen and phosphorus compounds, sulfides, and such major elements as Si, Na, K, Ca, Mg, Al, Fe, NH_4, SO_4 and Cl. It contains a host of minor elements such as Cr, Mn, Cu, Ni, Hg, Pb, Cd, Zn.

The quantity of domestic sludge produced in the United States has been estimated from information given in Fair et al[6]. The calculation is illustrated in Table III and given in condensed form below:

Basis: 1 million gallons of sewage (10,000 capita)

	Raw*	Digested*
primary	1190 lb.	576 lb.
waste activated(W.A.S.)	660 lb.	
primary & W.A.S.	1850 lb.	890 lb.

*dry solids basis

For estimating purposes, approximate sludge production is about one ton per million gallons of sewage. Based on the estimate that the per capita production of sewage is 100 gallons per day, 10,000 people will produce one million gallons of sewage and one ton (dry basis) of sludge per day. If the sludge is digested throughly, the sludge mass will be reduced to 1000 pounds per day.

The Federation of Sewage and Industrial Wastes Association - Manual of Practice No. 2[7] provides information given in Table IV on the content of major components of various type sludges. As the table shows, sludges contain about 70 percent volatile matter before digestion. This figure drops to about 50 percent after digestion. Ash content of sludge is higher than might be expected, mostly because of the presence of particulate mineral matter (sand and clay). Digested sludge is very high in ash because the sludge loses only volatile matter during digestion. Grease and fat are highly variable. Protein content of waste activated sludge is high because the sludge contains a large proportion of bacterial cells.

The heat of combustion of sludges depends largely on the proportion of volatile solids. Table V, which has been taken from Burd[8], shows the range of values encountered. Heat of combustion is best determined by measurement in a bomb calorimeter. However, it can be calculated from the elemental analysis [8,9] or estimated from the volatile solids content [10].

III. Metals and Other Elements in Sludge

Characteristics of sludges vary from plant to plant and from region to region. As to be expected, the metals content of sludges vary greatly. Analyses are summarized in Table VI. A more complete form of this table, showing

sources of the data as well as range and number of measurements averaged, is given as Appendix Table A-1. These analyses represent samples taken from treatment plants mostly from the Midwest with a few from the West Coast. Much more data yet remain to be collected. Analyses were found for 31 elements, many in trace amounts and determined by emission spark spectrograph.

Not surprisingly, the major elements are calcium, magnesium, sodium, potassium, aluminum, iron, zinc, sulfur, and silicon. Sodium and potassium do not form precipitates under the conditions of wastewater treatment. They very likely were present in the aqueous phases and precipitated as the sludge was dried for analysis. Titanium is an unexpectedly major element found in sludge.

The Rockford, Illinois sewage treatment plant is located in a metal fabrication industrial area[5] and the following table illustrates what metal content can be expected in the types of sludge produced by the plant:

Metal Content of Sludges at Rockford

Sludge Type	Concentration in Sludge (mg/g)			
	Chromium	Copper	Zinc	Nickel
Primary (mg/g)	5	2	11	0.5
Secondary (mg/g)	7	4	8	0.8
Trickling Filter (mg/g)	18	13	17	3
Digesting Sludge (mg/g)	8	2	10	0.5
Filtrate from Digesting Sludge, thru 0.45 μ filter (mg/l)	0.8	1.0	0.7	nil

A comparison of the concentrations of the metals in this table with the data for the same metals in Table VI, indicate that a concentration of metal-working or electroplating industry can increase the content of certain metals in the

sludge by two or threefold. The low concentration of the metals in filtrate from digesting sludge indicate that the metals are present in insoluble form.

IV. Air Pollution From Sludge Incineration

Table VI shows the presence of metals which could be very toxic, such as lead, cadmium, beryllium, arsenic, mercury, vanadium, nickel, manganese, and chromium. Unfortunately, very little information is on hand with respect to amounts of metals being discharged into the atmosphere as a result of incinerating sludge. Cross, Drago, and Francis,[11] reported the following mass emission rates of 7 metals per ton of mixed sludge plus refuse burned:

EMISSION RATE: GRAMS/TON OF MATERIAL INCINERATED								
Incinerator Loading Condition	Total Particulates	Cu	Ni	Zn	Fe	Pb	Cr	Cd
Refuse and Sludge Wt. Ratio 3.5 to 1	3282 g/ton	25.9	2.2	81.7	34.0	43.6	4.1	0.26
	% 100.0	0.79	.061	2.5	1.0	1.3	0.12	0.008

The data show that, although the particulate loading is low relative to the total charge, metals probably originating from industrial waste or sludge are present in noticeable quantities in the particulates. The data do not permit a reliable estimate to be made of the contribution of the sludge to the metal found in the particulates.

Mercury is an example of a substance which presents special problems during incineration. High temperatures during incineration decompose mercury compounds to volatile mercuric oxide or metallic mercury. Fortunately, the quantity of mercury involved is small. Dean[12] obtained an estimate from an incinerator manufacturer that approximately 4000 tons per day of sludge, are incinerated. If the average Hg concentration in the sludge is 0.01 mg/g, eighty pounds of mercury would be expelled into the atmosphere over the United States. This amount is insignificant, particularly in light of the estimated 3000 tons per day of mercury which is discharged into the atmosphere from the burning of coal over the

earth[13].

The forms in which metals are found in sludge will influence their behavior on incineration. For example, if cadmium is present in the sludge, in solution as cadmium chloride, it could volatilize upon incineration. If it is present as a precipitated hydroxide, it would probably decompose to the oxide, but would not volatilize at the temperatures of incineration. The chemistry of the metals in sludges needs investigation. However, it is felt that most of the toxic metals with the exception of mercury will not disproportionately appear in stack gases because of volatilization, but will be converted to oxides and appear in the particulates removed by scrubbers or electrostatic precipitators and in the ash.

Gaseous pollutants which could be released by sludge incineration are hydrogen chloride, sulfur dioxide, oxides of nitrogen, and carbon monoxide. Carbon monoxide is no threat if the incinerator is properly designed and operated. Hydrogen chloride, which would be generated by decomposition of certain plastics, is no problem at all, because the plastics are not presently discharged into sewers. Consideration of the possibility of SO_2 and NO_x pollution is aided by examination of the sulfur and nitrogen content of sludges. Unterberg, et al[14] give the following average analyses of four sludges:

% Ash	22.6
% C	50.3
% H	5.7
% S	0.67
% N	3.07

Sulfur content is relatively low. In addition, much of this sulfur is probably in the form of sulfate, which originated in the wastewater. Sulfur dioxide is not expected to be a serious problem.

The temperature in sludge incineration is typically less than 1800°F. At these temperatures, formation of oxides of nitrogen from the nitrogen in

the air is low. However, sludge typically has a high nitrogen content, probably from proteinaceous compounds and ammonium ion. Data are not available for predicting whether a high proportion of these materials will be converted to oxides of nitrogen on combustion. Farrell[15] has examined limited data available and noted that concentration of oxides of nitrogen from sludge incineration were less than 100 ppm. Considering this low concentration, the much higher concentrations obtained in coal burning, and the small amount of sludge incinerated relative to coal, he concluded that the production of oxides of nitrogen will probably not limit the use of incineration for disposing of sludges.

In addition to the major air pollutants resulting from the burning of sludge, toxic substances can arise due to the content of pesticides or other organic compounds in the sludge[16]. Very little information is available on specific organic compounds in sludge. There is, however, a limited amount of information on pesticides in sludge. Sludge samples from two wastewater treatment plants were subjected to electron-capture gas chromatographic analysis by EPA chemists, Advanced Waste Treatment Research Laboratory, Cincinnati, Ohio, who reported the following results[17]:

	Little Ferry, New Jersey	Madison - Chatham, New Jersey	
		Sample #1	Sample #2
Insecticide	ppm	ppm	ppm
Dieldrin	0.30	0.21	0.17
Chlordane	9.44	6.56	7.26
DDD	0.97	0.43	0.43
PCB-Arochlor 1254	6.2 to 6.6	1.5 to 1.7	3.1 to 3.3

The fate of these substances during incineration is not known. Despite their physiological activity, they are stable to oxidation and could possibly be vaporized rather than decomposed during incineration.

V. Pollution of Land or Water

As mentioned before, the ash remaining from incineration amounts to 15 to 45 percent of the total dry mass of the sludge, depending on the type of sludge being incinerated. The disposal of the ash could pose a pollutional threat to land or water. Consequently, physical and chemical characteristics of the ash and solubility of its salts need to be known. Dr. D. H. Gray of the University of Michigan[18] reports the chemical and physical analysis of sludge ash from six waste treatment plants around the country. These data are shown in Tables VII and VIII.

Dr. Gray's data show that the major components of ash, reported as oxides, are silicon, aluminum, iron, calcium, and phosphorus. The ashes are moderately basic, and have water solubility under about 2.0 weight percent when the ash is leached with about 20 times its mass of water. The silicon, aluminum, iron, phosphorus, and most of the calcium are probably fixed in highly insoluble form. The sodium, potassium, and some of the calcium could probably be leached away as hydroxides.

VI. Future Information Needs

Characteristics of sludges to be incinerated vary a great deal. Consequently, information on properties of sludges should be obtained from localities throughout the country. Availability of analyses of various type sludges should aid in development or planning of an incineration program. Analysis of sludges should be complete and especially extended to determinations of minor trace elements, pesticides, mercury, and the like. Much more information on sludge analyses than here presented is scattered throughout the literature. A literature survey or personal inquiries should unearth a multitude of facts.

Information is needed on properties of the ash that is produced as a result of incineration. Ash should be exposed to simulated or actual landfill conditions

to determine the degree of hazard it presents to the environment. The landfill disposal of a sludge ash would be a meaningless gesture if the leachate from the landfill area polluted a nearby stream.

The chemistry of the potentially hazardous substances in sludge should be investigated by literature study and experimentation so that predictions can be made of their behavior upon incineration. Material balances on major and minor constituents of sludge should be made on existing incinerators to provide badly needed empirical knowledge and to check validity of predictions.

As an ultimate goal of our informational needs, it should be possible to predict accurately the fate of toxic metals, pesticides, and other hazardous substances in wastewater treatment including ultimate disposal of residues. The proportion of these substances that is removed as sludge in various types of waste treatment processes should be known, as well as their behavior on incineration.

B. V. Salotto
Dr. J. B. Farrell

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16. National Tuberculosis and Respiratory Disease Association, Air Pollution Primer, New York (1969).

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TABLE I

MATERIALS REMOVED BY CONVENTIONAL SEWAGE TREATMENT

Treatment Plant	Percent Removals			
	Suspended Solids	COD	Nitrogen	Phosphorus
Bryan, Ohio	87	94	61	-
Richmond, Indiana	86	90	16	-
Rockford, Illinois	58	61	13	-
Grand Rapids, Mich.	56	61	30	-
Fairborn, Ohio	61	69	38	-
Archbold, Ohio	85	83	53	17
Pilot Plant *	95	89	40	40
Pilot Plant *	92	81	33	25

* Facilities at R. A. Taft Water Research Center.

TABLE II

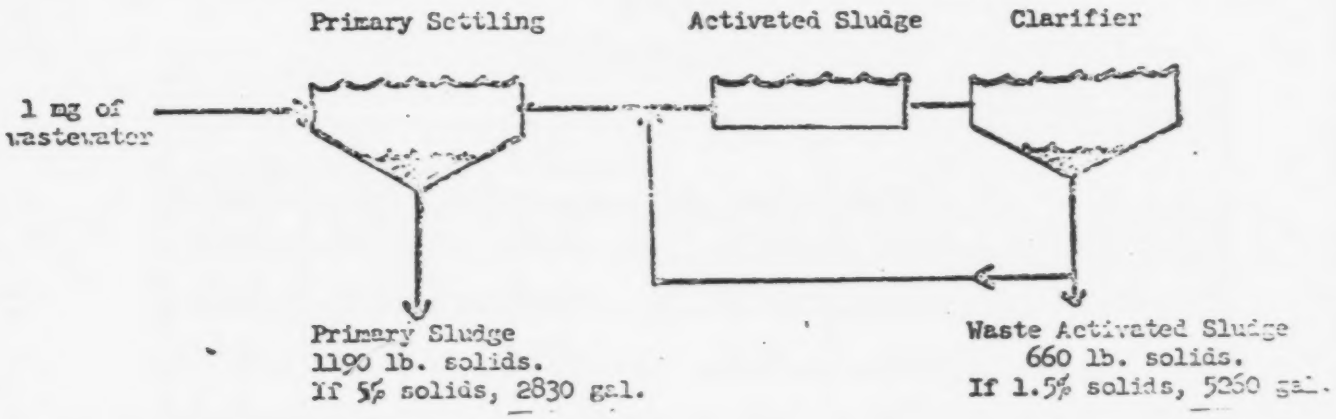
FATE OF METALS THROUGH SEWAGE TREATMENT PROCESS

Metal	Influent Sewage, mg/l		Final Effluent, mg/l		Percent Immobilized in Sludge
	Average	Range	Average	Range	
Bryan, Ohio (5-Day Compositing Period)					
Chromium	0.8	0.6-1.1	0.2	0.2-0.3	-
Copper	0.2	0.2-0.3	0.1	0.04-0.1	-
Nickel	0.05	0.03-0.1	0.05	0.03-0.1	-
Zinc	2.2	1.4-3.0	0.2	0.2-0.3	-
Grand Rapids, Michigan (14-Day Compositing Period)					
Chromium	3.6	0.7-5.6	2.5	1.0-3.3	40
Copper	1.4	0.7-2.4	1.6	0.4-2.9	16
Nickel	2.0	1.3-3.4	1.8	1.0-2.5	12
Zinc	1.5	0.6-2.5	0.8	0.6-1.2	58
Richmond, Indiana (14-Day Compositing Period)					
Chromium	0.8	0.2-2.1	0.2	0.01-0.5	82
Copper	0.2	0.1-0.4	0.07	0.04-0.2	73
Nickel	0.03	0.01-0.1	0.02	0.01-0.03	78
Zinc	0.3	0.1-0.5	0.1	0.1-0.2	85
Rockford, Illinois (13-Day Compositing Period)					
Chromium	1.8	0.5-2.9	1.2	0.6-1.5	37
Copper	1.4	0.6-3.3	1.0	0.5-3.6	23
Nickel	0.9	0.2-1.9	0.9	0.5-1.4	8
Zinc	2.7	1.2-3.4	1.3	0.8-1.7	53

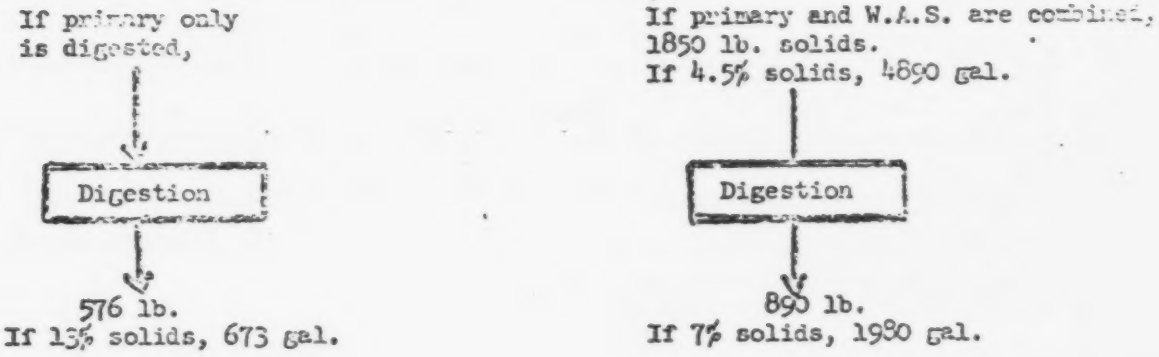
TABLE III
SLUDGE QUANTITIES *

Basis: 1 million gallons of domestic wastewater

Quantities Before Digestion



Quantities After Anaerobic Digestion



* These quantities were taken from an example in Fair, G. M., Geyer, J. C. and Okun, D. A., "Water and Wastewater Engineering, Vol. 2: Water Purification and Wastewater Treatment and Disposal," pp. 36-6 to 36-8, J. Wiley and Sons, N. Y. (1968).

TABLE IV

MAJOR COMPONENTS OF SLUDGE*

Constituent	Types of Sludge				
	Raw Primary	Digested	Waste Activated	Filter Cake Raw	Filter Cake Digested
Volatile Matter	60-80	45-60	62-75	55-75	40-60
Ash	20-40	40-45	25-38	25-45	40-60
Insoluble Ash	17-35	35-50	22-30	15-30	30-45
Greases & Fats	7-35	3-17	5-12	5-30	2-15
Protein	22-28	16-21	32-41	20-25	14-30
NH_4NO_3	1-3.5	1-4	4-7	1.3	1.3-1.6
P_2O_5	1-1.5	0.5-3.7	3-4	1.4	0.5-3.5
K_2O		0-4	0.86		
SiO_2		20-22	12		
Fe		5.4	7.1		
Cellulose	10-13	10-13	7.8	8-10	8-12

*All data are presented on a dry basis.

TABLE V

HIGH HEAT OF COMBUSTION OF SLUDGES* (TOTAL DRY SOLIDS BASIS)

Material	Combustibles (%)	Ash (%)	B.t.u./Pound
Grease and scum	88.5	11.5	16,750
Raw sewage solids	74.0	26.0	10,285
Fine screenings	86.4	13.6	8,990
Ground garbage	84.8	15.2	8,245
Digested sewage solids and ground garbage	49.6	50.4	8,020
Digested sludge	59.6	40.4	5,290
Grit	33.2	69.8	4,000

*Source: Burd, R. S., "A Study of Sludge Handling and Disposal", U. S. Dept. Int., FWPCA, p. 248, WPC Research Series WP-20-4 (May 1968).

TABLE VI

SUMMARY OF MAJOR AND MINOR ELEMENTS IN SLUDGE
(mg/g dried sludge)

Element	Primary Sludge	Activated Sludge	Digested Sludge
Aluminum	5.1	10.0	17.9
Antimony	n.a.*	n.a.	0.9
Arsenic	< 1.2	1.2	n.a.
Barium	2.2	1.2	1.4
Beryllium	0.0025	0.0035	0.0025
Boron	0.10	0.070	0.046
Cadmium	< 0.19	0.35	0.26
Calcium	n.a.	13.0	33.5
Chromium	2.0	.3	2.3
Cobalt	0.22	0.002	n.a.
Copper	2.0	1.1	1.6
Gallium	0.06	0.05	0.05
Iron	16.1	40.5	30.6
Lead	1.0	1.5	1.9
Magnesium	10.6	7.0	7.5
Manganese	0.78	0.31	0.98
Mercury	0.005	0.02	n.a.
Molybdenum	0.36	0.20	0.25
Nickel	0.52	0.38	0.38
Phosphorus	3.8	19.9	12.8
Potassium	n.a.	4.2	2.8
Silicon	n.a.	40.0	162
Silver	0.24	0.15	0.20
Sodium	4.0	4.4	6.2
Strontium	0.13	0.16	0.26
Sulfur	n.a.	10.1	12.3
Tin	0.95	0.50	0.60
Titanium	14.8	11.8	14.2
Vanadium	2.1	0.7	5.2
Zinc	6.9	3.3	4.0
Zirconium	1.7	10.0	2.0

*n.a. - not available.

TABLE VII - CHEMICAL ANALYSIS OF SOME SEWAGE SLUDGE ASHES

Source of Ash	Chemical Composition - Per Cent By Weight											Loss On Ignition
	SiO_2	Al_2O_3	Fe_2O_3	MgO	Cao	Free CaO	Na_2O	K_2O	B	P_2O_5	SO_3	
Pontiac (Mich.)	32.54	9.60	9.47	2.07	36.92	1.12	0.41	0.66	0.015	7.01	0.01	1.0
St. Paul (Minn.)	24.87	13.48	10.81	2.61	33.35	1.06	0.26	0.12	0.006	9.88	2.71	1.62
Kansas City (Mo.)	57.67	15.00	8.50	0.85	8.64	0.03	0.45	0.35	0.02	4.43	3.42	0.31
Saginaw (Mich.)	28.18	4.63	8.68	2.20	29.86	1.62	0.32	0.07	0.01	3.86	2.87	15.13
South Tahoe (Cal.)	23.85	16.34	3.44	2.12	29.76	1.16	0.73	0.14	0.02	6.87	2.79	2.59
Cromwell (Conn.)	14.39	4.73	24.40	1.35	26.39	0.26	0.13	0.07	0.01	8.63	1.68	14.67

TABLE VIII - SUMMARY OF PHYSICO-CHEMICAL PROPERTIES OF SLUDGE ASHES

Source of Ash	Natural Moisture Content (%)	Specific Gravity	Grain Size Distribution (M.I.T. Scale)			pH(1)	Water Soluble Salts (%)	Electrical(2) Conductivity of Ash Leachate (μmhos/cm)
			Sand (%)	Silt (%)	Clay (%)			
Pontiac (Mich.)	0.2	2.95	7	93	0	11.9	?(3)	452
St. Paul (Minn.)	1.2	2.85	53	47	0	10.7	0.22	1740
Kansas City (Mo.)	0.2	2.44	24	69	7	11.3	0.87	831
South Tahoe (Calif.)	0.3	2.87	14	86	0	12.8	?	3615
Saginaw (Mich.)	0.8	2.77	17	82	1	10.7	0	2094
Cromwell (Conn.)	64.7	2.85	15	72	13	11.5	1.52	1696
Cuyahoga (Ohio)	0.2	2.96	6	94	0	11.5	?	1492
Ann Arbor (Mich.)	0.1	2.75	25	69	6		1.16	2252

Notes:

(1) Measured on a settled suspension with an ash to dist. water ratio of 1:5.

(2) 125 gms. of ash leached with 2 liters of dist. water.

(3) Some samples increased in weight after leaching; this may have been caused by hydration of certain ash constituents such as the free lime.

TABLE A-1

SUMMARY OF MAJOR AND MINOR ELEMENTS IN SLUDGE*
(MILLIGRAM PER GRAM DRIED SLUDGE)

Elemental Analysis	Primary Sludge			Activated Sludge			Digested Sludge		
	Average	Range	No. in Sample	Average	Range	No. in Sample	Average	Range	No. in Sample
Al	5.10	10.78-1.83	3	10.0	17.0-4.35	3	17.86	36-7.75	4
Sb							0.897	.984-.81	2
As	< 1.24	<1.49-<0.83	3	1.20	2.22-.101	3			
Ba	2.25	5.0-0.11	11	1.15	3.0-.22	4	1.36	4.01-.10	15
Be	0.0025	0.0030-0.0017	3	0.0035	.0044-.0026	2	0.0025	.0065-.0012	11
B	0.104	0.15-0.07	11	0.070	.22-.006	9	0.046	.149-.003	17
Cd	< 0.188	<0.30-0.0034	4	0.35	.44-.26	2	0.264	.50-.001	10
Ca				13.0	18.0-9.0	7	33.5	112.-4.9	15
Cr	2.05	9.0-0.08	15	4.31	17.-0.1	8	2.28	11.0-.10	28
Co	0.217	0.5-.05	6	0.0016	.0016	1			
Cu	2.00	6.0-0.0083	17	1.10	2.6-.372	13	1.65	16.0-.10	39
Fe	16.1	20.0-2.86	12	40.5	96.6-4.83	9	30.65	60.6-10.09	19
Pb	1.01	2.14-0.33	3	1.52	2.09-.51	3	1.89	7.52-.18	18
Mg	10.6	15.0-5.0	8	7.04	10.9-3.01	7	7.49	13.0-1.0	17
Mn	0.781	1.0-.16	11	0.310	.93-.065	9	0.976	6.04-.06	17
Hg	0.0046	0.006-.0030	2	0.016	.020-.012	2			
Mo	0.362	1.0-.05	11	0.197	0.89-.006	8	0.254	1.29-.002	24
Ni	0.522	2.0-.0014	17	0.378	2.0-.04	8	0.372	3.0-.03	27
P	3.78	6.83-1.49	3	19.9	32.2-11.07	8	12.75	25.13-1.18	15
K				4.21	7.16-2.49	6	2.76	6.15-.83	13
Si				39.5	39.5	1	162.	334.-73.	3
Ag	0.243	1.0-.08	11	0.150	.22-0.1	3	0.195	.50-.08	4
Na	3.96	10.-0.5	8	4.44	7.88-1.0	2	6.15	10.-2.0	5
Sr	0.13	0.14-0.12	3	0.155	0.21-.10	2	0.26	.26	1
S				10.1	11.6-7.6	6	12.3	32.5-1.64	14
Sn	0.95	2.0-0.5	8	0.5	0.5	1	0.60	.70-.50	3
Ti	14.8	20.-5.0	8	11.8	20.-.50	3	14.2	20.-1.0	3
V	2.09	15.-0.3	11	0.70	0.89-0.51	3	5.20	10.-.32	4
Zn	6.87	35.-.34	18	3.29	6.3-.13	13	4.04	11.-.5	39
Zr	1.72	10.9-0.3	8	10.0	10.0	1	2.03	5.0-.10	3
Ga	0.063	0.1-.01	7	0.05	.05	1	0.05	.05-.05	3

*Compiled from the following sources: (See attached reference list)

APPENDIX TABLE A-1

SUMMARY DATA OF TABLE
WERE DERIVED FROM THE FOLLOWING SOURCES OF INFORMATION:

1. U. S. Dept. Health, Education, and Welfare, "Land Reclamation Project--An Interim Report," Grant No. DO-01-00089 (USPHS), 1968.

2. J. F. Kopp to B. V. Salotto, Internal EPA memo, "Spectrographic Trace Metal Analysis of Dried Sludge Samples," (March 30, 1971).

3. Anderson, M. S., "Sewage Sludge for Soil Improvement," U. S. Dept. of Agriculture Circular No. 972 (Nov. 1955).

4. Balakrishnan, S., Williamson, D. E., and Okey, R. W., "State of the Art Review on Sludge Incineration Practice," U. S. Dept. of Interior, FWQA, WPC Research Series 17070 DIV 04/70.

5. Burd, R. S., "A Study of Sludge Handling and Disposal," U. S. Dept. of Interior, WPC Research Series WP-20-4 (May 1968).

6. Thompson, R. M., Zajic, J. E., and Lichti, E., "Spectrographic Analysis of Air-Dried Sewage Sludge," JWPCF 36(6), 752 (June 1964).

7. Anderson, M. S., "Comparison Analyses of Sewage Sludges," JWPCF 28(2), 133 (Feb. 1956).

8. U. S. Dept. of Interior, FWQA, "Engineering Feasibility Demonstration Study for Muskegon County, Michigan--Wastewater Treatment-Irrigation System," WPC Research Series 11010 FMY 10/70.

9. B. R. Sacks to J. B. Farrell, Internal EPA memo, "Heavy Metal Analyses of ORB Sediments and STP Sludges," (April 26, 1971).

10. B. V. Salotto to G. Walton, Internal HEW memo, "Heavy Metal Analyses of Sludge from Quincy, Illinois STP," (Sept. 9, 1963).

11. Barth, E. F., English, J. N., Salotto, B. V., Jackson, B. N., and Ettinger, M. B., "Field Survey of Four Municipal Wastewater Treatment Plants Receiving Metallic Wastes," JWPCF 37(8), 1101 (Aug. 1965).

12. Mather, P., "Experimental Work on the Treatment of Sewage and Sludge Containing High Concentrations of Zinc," J. Inst. Sew. Purif., Part V, 474 (1964).

13. Metropolitan Sanitary District of Greater Chicago, "The Beneficial Utilization of Liquid Fertilizer on Land," (Sept. 1968).

14. English, J. N., Barth, E. F., Salotto, B. V., and Ettinger, M. B., "A Slug of Chromic Acid Passes Through a Municipal Treatment Plant," Proc. 19th Purdue Industrial Waste Conf., Series 117, 493 (May 1964).

APPENDIX F

REPORT OF EMISSION TESTS

MADE PURSUANT TO CHAPTER 11 OF

THE NEW JERSEY AIR POLLUTION CONTROL CODE

N.W. BERGEN SEWAGE AUTHORITY

WALDWICK, N.J.

NEW JERSEY STATE DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF ENVIRONMENTAL QUALITY
BUREAU OF AIR POLLUTION CONTROL

MAY 20, 1971

INCINERATOR EMISSION TEST
N.W. BERGEN SEWAGE AUTHORITY
WALDWICK, N.J.

PURPOSE:

The purpose of this test was to determine whether the N.W. Bergen Sewage Authority's Incinerator Stack emissions were within the standards as prescribed by Chapter 11 of the Air Pollution Control Code.

PERSONNEL:

The test was performed by personnel of the New Jersey State Department of Environmental Protection, Bureau of Air Pollution Control. Those participating were:

Mark Pollak, Environmental Specialist
Marvin Makler, Senior Environmental Quality Field Worker
William Krimson, Environmental Quality Field Worker
Carl Wetterling, Environmental Quality Field Worker

The Department gratefully acknowledges the assistance and cooperation of the Sewage Authority and expresses its appreciation in particular to Mr. George Baer, Superintendent.

DATES OF TESTS:

May 3 and 4, 1971.

DESCRIPTION OF PLANT OPERATION:

The plant consists of primary settling, high rate biofiltration, secondary settling and chlorination. The sludge is disposed of by a thickening and incineration process.

The sludge is sprayed into a fluidized sand bed reactor (incinerator) and burned. The ash and gases from this process rise to the top of the incinerator, pass through a scrubber and are vented to a stack. The ash from the scrubber is disposed of in a landfill next to the plant.

PLANT OPERATING CONDITIONS:

Plant records indicated that the incinerator was operating normally during all test runs. The feed rate of solids to the incinerator during the test runs was continuous at 650 pounds per hour. The maximum designed burning rate is 1100 pounds per hour.

SAMPLING PROCEDURE:
Particulate:

The sampling was performed at approximately 13 feet above the stack inlet from the scrubber.

The sampling train arrangement is detailed in the attached diagram with the exception that the cyclone was not used. A stainless steel "button-hook" nozzle is attached to a heated glass probe. Connected in series to the nozzle and probe assembly are a dry glass (heated) fibre filter, a modified Greenburg-Smith Impinger (Condenser), a Greenburg-Smith Impinger with 100 ml of distilled water, a modified G-S impinger (knock-out), a desiccant (Drierite), a vacuum pump, a dry gas meter and an orifice meter. Prior to each sampling run a 6 point velocity traverse was made at the sampling location in order to determine isokinetic sampling rates.

CARBON DIOXIDE:

Carbon dioxide was sampled simultaneously with the particulate sampling at the scrubber inlet. The sampling rate was set at 0.3 cubic feet per hour.

The sampling train consisted of a 1/8-inch O.D. stainless steel probe, a condenser, a 14 liter aluminized plastic bag in an evacuation bottle, a vacuum pump and a rotometer all connected in series.

In order to determine the CO_2 concentration from the burning sludge the auxiliary fuel from the bed guns were turned off and CO_2 measurements were taken in the stack gases with a Fyrite CO_2 Sampler.

RESULTS:

RUN	DATE	SO_2% (by vol.)	ODOR (from S.)	SMOKE (Ringl.)	CO_2(% by vol.) (less aux. fuel)	Particulate Concentration (GRS/SCF@12%CO_2
	5/3/71	*	None	< 1	4.0	0.020
	5/4/71	*	None	< 1	5.1	0.031
	5/4/71	*	None	< 1	4.0	0.048

*Below detectable limits.

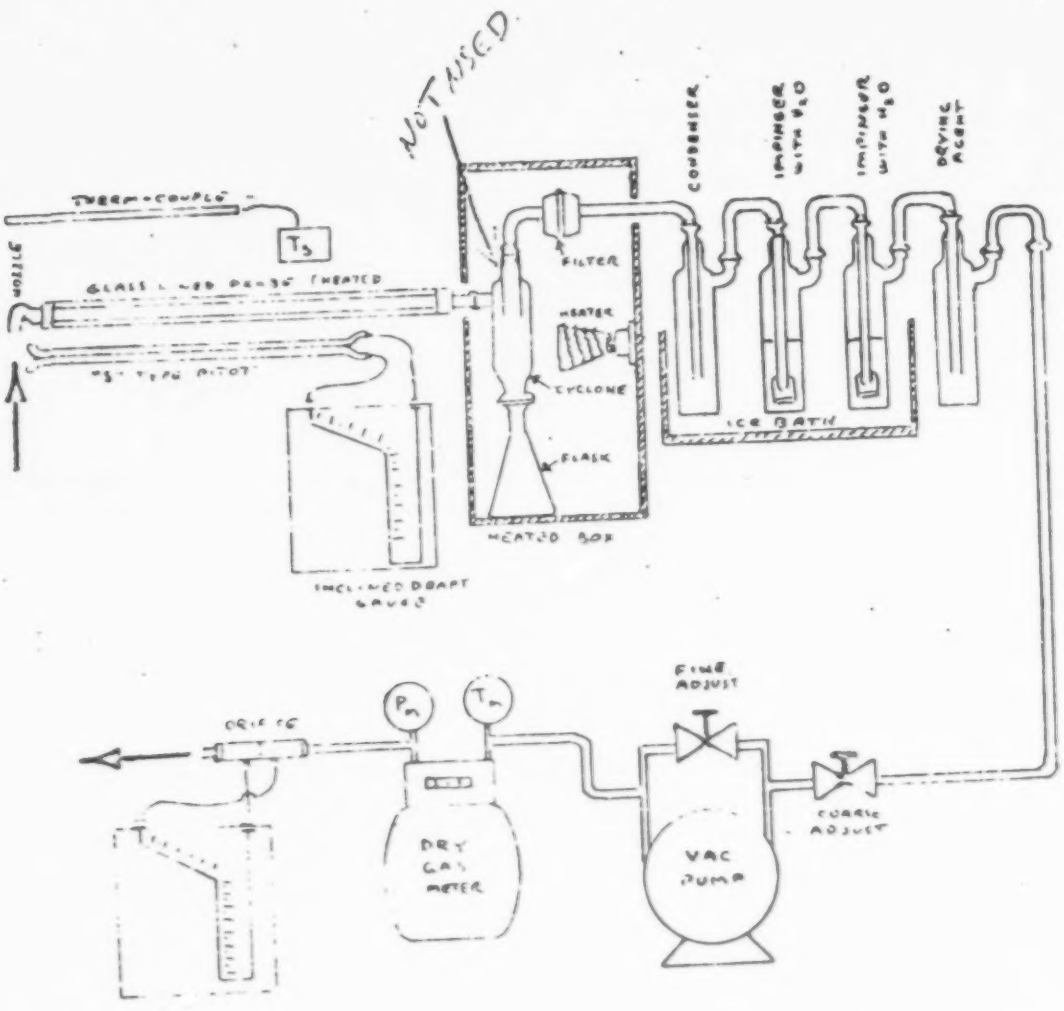
CONCLUSIONS:

The test results indicated that the particulate concentration in the incinerator stack gases were within the allowable concentration as prescribed under Chapter 11 of the Air Pollution Control Code.

Bernhardt V. Lind

Bernhardt V. Lind
Supervisor, Technical Services
Bureau of Air Pollution Control

MP/BVL:jar



SAMPLING TRAIN WITH EXTERNAL CYCLONE-IMPINGER ARRANGEMENT

FIGURE 8
Part 4, section II

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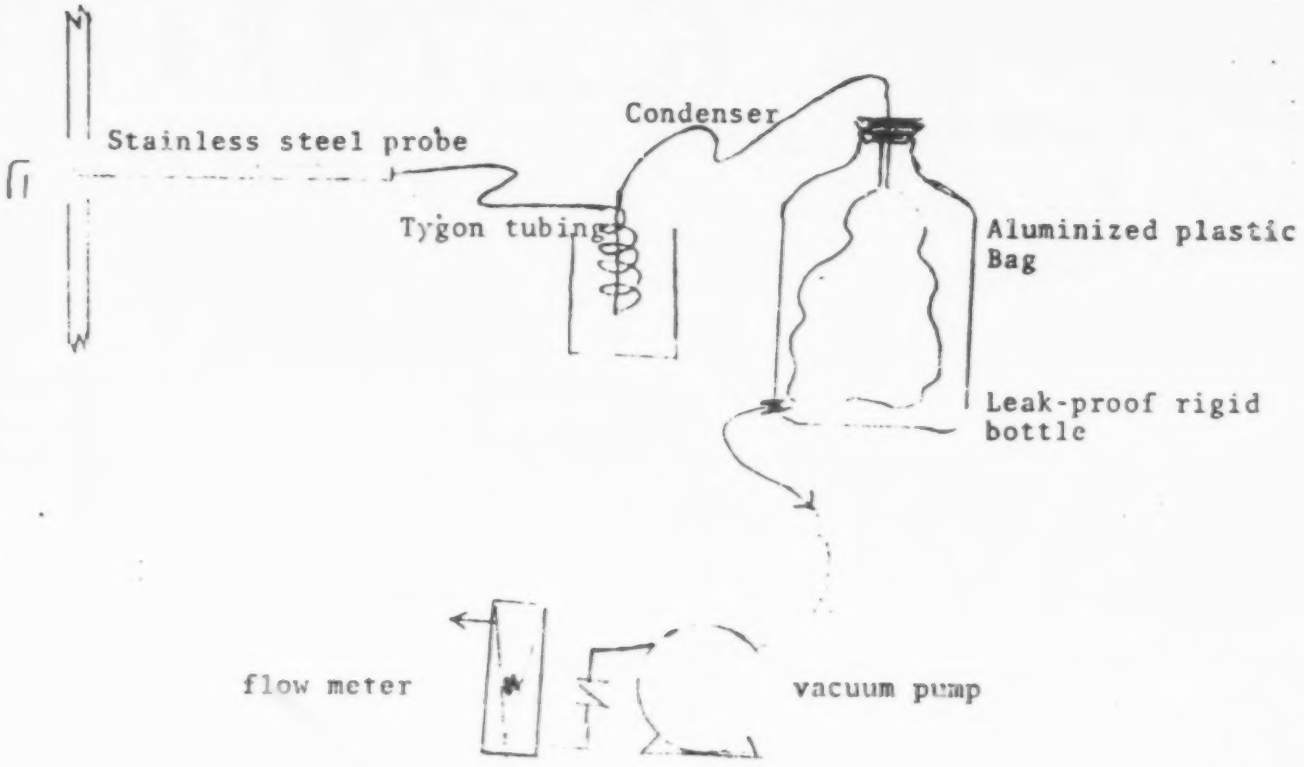

DIAGRAM OF CARBON DIOXIDE SAMPLING TRAIN

STATE OF NEW JERSEY
AIR POLLUTION CONTROL PROGRAM
STACK TESTING
FIELD DATA REPORT

PLANT	Vol Foam Co. Ty Inc.	DATE	5/3/71
STREET	[redacted]	RUN No.	1
CITY	Hardwick	TIME: START	2 10 PM
STACK	Incinerator stack	FINISH	3 10 PM
N.J. No.	Incinerator stack	TEST PERIOD (minutes)	60
CHAPTER No.	11	DRY GAS METER READING: START	242.700
NOZZLE DIAMETER (inches)	1/4	FINISH	283.151
DRY BULB TEMPERATURE (°F.)	80	DRY GAS VOLUME (ft^3)	40.451
WET BULB TEMPERATURE (°F.)	78	CONDENSATE (ml.)	22
WATER VAPOR BY VOLUME (%)	3.4	THIMBLE No.	N/A
TEST MADE BY:	T. Polak	FILTER No.	121

DISTANCE FROM PORT TO SAMPLE POINT (inches)											
1	2	3	4	5	6	7	8	9	10	11	12
3/4	2 1/2	5	12	14 1/2	16 1/4						

PORT	POINT	PITOT △P	ORIFICE △H	STACK GAS TEMP. °F.	DRY GAS TEMP. °F.	$\sqrt{\Delta P}$
EAST	1	.21	.74	80	52	.46
	2	.36	1.03	80	56	.600
	3	.30	.55	80	60	.545
	4	.28	1.1	80	60	.616
	5	.52	1.45	80	60	.721
	6	.50	1.40	80	60	.707
SOUTH	1	.38	1.1	80	57	.616
	2	.39	1.1	80	56	.616
	3	.38	1.1	80	60	.616
	4	.50	1.40	80	60	.707
	5	.55	1.55	80	60	.742
	6	.46	1.3	80	60	.678
= TOTAL =				960	676	7.177
AVERAGE =				80	56	.631

AVERAGE △P = .41

STACK DIAMETER: 17 3/8 (inches)

STACK AREA: 1.65 (sq.ft.)

STACK GAS TEMPERATURE: 540 (°R.)

Vel = $2.48 \cdot \sqrt{\Delta P}$ T
= 36.87 fps

Vol = Vel x Area x 60
= 3650 cfm

RECTANGULAR STACK OR DUCT DIMENSIONS:

N/A

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STATE OF NEW JERSEY
AIR POLLUTION CONTROL PROGRAM
STACK TESTING
FIELD DATA REPORT

PLANT	N.W.I. Bergen Co. Sewage Authority	DATE	5/4/71
STREET	Wyckoff Ave	RUN No.	2
CITY	Waldwick	TIME: START	9:35 AM
STACK	Incinerator	FINISH	10:35 AM
N.J. No.	N/A	TEST PERIOD (minutes)	60
CHAPTER No.	11	DRY GAS METER READING: START	283.202
NOZZLE DIAMETER (inches)	1/4	FINISH	324.942
DRY BULB TEMPERATURE (°F.)	78	DRY GAS VOLUME (ft^3)	41.740
WET BULB TEMPERATURE (°F.)	78	CONDENSATE (ml.)	18
WATER VAPOR BY VOLUME (%)	3.4	THIMBLE No.	N/A
TEST MADE BY:	M. Pollak	FILTER No.	120

DISTANCE FROM PORT TO SAMPLE POINT (inches)											
1	2	3	4	5	6	7	8	9	10	11	12
3/4	2 1/2	5	12	14 1/2	16 1/4						

PORT	POINT	PITOT ΔP	ORIFICE ΔH	STACK GAS TEMP. °F.	DRY GAS TEMP. °F.	√ΔP
East	1	.30	.84	78	62	.548
	2	.30	.84	78	62	.548
	3	.30	.84	78	62	.548
	4	.42	1.22	78	62	.648
	5	.38	1.15	78	62	.625
	6	.56	1.60	78	62	.748
	1	.44	1.24	78	62	.666
	2	.44	1.24	78	62	.666
	3	.28	.78	78	62	.530
	4	.58	1.69	78	62	.762
	5	.54	1.61	78	62	.748
	6	.60	1.71	78	62	.775
= TOTAL =				936	744	3.912
AVERAGE =				78	62	.651

AVERAGE ΔP = .4448

STACK DIAMETER: 17 3/8 (inches)

STACK AREA: 1.65 (sq.ft.)

STACK GAS TEMPERATURE: 540 (°R.)

Vel = 2.48 * √ΔP T
= 38.36 fps

Vol = Vel x Area x 60
= 3785 cfm

RECTANGULAR STACK OR DUCT DIMENSIONS:

N/A

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STATE OF NEW JERSEY
AIR POLLUTION CONTROL PROGRAM
STACK TESTING
FIELD DATA REPORT

PLANT	BERGEN CO. SEWER AUTH	DATE	5/4/11
STREET	KYCOFFE AVE	RUN No.	3
CITY	WALDWICK	TIME: START	11:30AM
STACK	INCINERATOR	FINISH	12:30 PM
N.J. No.	N/A	TEST PERIOD (minutes)	60
CHAPTER No.	11	DRY GAS METER READING: START	374.924
NOZZLE DIAMETER (inches)	1/4	FINISH	36.3-832
DRY BULB TEMPERATURE (°F.)	77	DRY GAS VOLUME (ft.3)	38.908
WET BULB TEMPERATURE (°F.)	77	CONDENSATE (ml.)	30
WATER VAPOR BY VOLUME (%)	3.4	THIMBLE No.	N/A
TEST MADE BY:	M. POLLAK	FILTER No.	110

DISTANCE FROM PORT TO SAMPLE POINT (inches)

1	2	3	4	5	6	7	8	9	10	11	12
3/4	2 1/2	5	12	19 1/2	16 1/4						

PORT	POINT	PITOT ΔP	ORIFICE ΔH	STACK GAS TEMP. °F.	DRY GAS TEMP. °F.	√ΔP
East	1	.24	.69	78	64	.490
	2	.28	.78	78	64	.530
	3	.25	.715	78	64	.500
	4	.45	1.30	78	64	.671
	5	.68	1.95	78	64	.825
	6	.50	1.47	78	64	.707
West	1	.30	.84	78	64	.548
	2	.36	1.05	78	64	.600
	3	.13	.38	78	64	.364
	4	.40	1.17	78	64	.633
	5	.57	1.70	78	64	.755
	6	.62	1.75	78	64	.787
	TOTAL =			936	768	
	AVERAGE =			78	64	
					AVERAGE ΔP =	.3806

STACK DIAMETER: 17 3/8 (inches)

STACK AREA: 1.65 (sq.ft.)

STACK GAS TEMPERATURE: 538 (°R.)

Vel = 2.48 * √ΔP T
= 35.48 fps

Vol = Vel x Area x 60
= 3513 cfm

RECTANGULAR STACK OR DUCT DIMENSIONS:

N/A

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... sludge + Recycle feed = 11.0% ... ratio

DERIVATION OF % ISOKINETIC SAMPLING RATE FORMULA

DEFINITIONS:

T_s = Flue gas temperature in degrees F.

V_m = Volume of gas sampled as measured by meter in cubic feet

T_m = Temperature at meter in degrees F.

D_n = Diameter of sampling nozzle in inches

T = Duration of sampling time in minutes

Q = Percent moisture in flue gas expressed as a decimal

V_n = Sampling nozzle gas velocity in feet per second

V_s = Flue gas velocity at some given point in feet per second

V_t = Total gas sampled converted to flue conditions in cubic feet

A_n = Area of sampling nozzle in square feet

DERIVATION:

1. % Isokinetic Sampling $= \dfrac{V_n}{V_s} \times 100\%$

2. $V_n = \dfrac{V_t}{A_n \times T \times 60}$

3. $A_n = \dfrac{\pi \times (D_n)^2}{4 \times 144}$

Substitute (3) for A_n in (2) to obtain (4).

4. $V_n = \dfrac{4 \times 144 \times V_t}{\pi \times (D_n)^2 \times T \times 60}$; Let: $\dfrac{4 \times 144}{\pi \times 60} = K_1$

Substitute K_1 in (4) to obtain (5).

5. $V_n = \dfrac{V_t}{(D_n)^2 \times T} \times K_1$

$V_t = V_m \times \dfrac{(T_s + 460)}{(T_m + 460)} \times \dfrac{1}{1-Q}$

Substitute (6) for V_t in (5) to obtain (7).

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7. $$V_n = \frac{V_m \times (T_s + 460)}{(D_n)^2 \times (T_m + 460) \times (1-Q) \times T} \times K_1$$

Substitute (7) for V_n in (1) to obtain (8).

8. $$\% \text{ Isokinetic Sampling} = \frac{V_m \times (T_s + 460) \times 100}{(D_n)^2 \times (T_m + 460) \times (1-Q) \times T \times V_s} \times K$$

9. Let: $K_1 = 3.055$

$K_2 = 100$

$K_3 = K_1 \times K_2 = 3.055 \times 100 = 305.5$

Substitute K_3 in (8) to obtain (10).

10. $$\% \text{ Isokinetic Sampling} = \frac{305.5 \times V_m \times (T_s + 460)}{(D_n)^2 \times (T_m + 460) \times (1-Q) \times T \times V_s}$$

STATE OF NEW JERSEY
AIR POLLUTION CONTROL PROGRAM
STACK SAMPLING
% ISOKINETIC SAMPLING CALCULATIONS

PLANT	North West Bergen County Sewer Authority
STREET	Wycoff Ave.
CITY	Waldwick
STACK	Incinerator
N.J. NO.	
CHAPTER NO.	11

FIELD & LAB. DATA	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5
DATE	5/3/71	5/4/71	5/4/71		
T_s (deg. F)	80	78	78		
V_m (CF)	40.451	41.94	38.90		
T_m (deg. F)	58	62	64		
D_n (inches)	.250	.250	.250		
T (minutes)	60	60	60		
Q (% as a decimal)	.034	.034	.034		
V_s (ft./ sec.)	36.87	35.36	35.48		
% ISOKINETIC SAMPLING	96.5	95.0	95.0		

CALCULATIONS BY : A. SCHUCK & M. MAHLER

DATE : 5/5/71

LABORATORY REPORT - STACK SAMPLING

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Air Pollution Control Program, New Jersey State Dept. of Health

Name of Company [illegible]

Location of Stack [illegible]

Stack Designation [illegible] INCINERATOR

Date Sampled 5-3-71 5-4-71

Analysis Required [illegible]

Samples Collected by [illegible] Date (s) _____

CHAPTER 20 — XI

A.S. No.	Field No.	Run No.	RESULT OF ANALYSIS	Unit	
3993	[illegible]	1	0.0088	[illegible]	[illegible]
			0.0081	[illegible]	[illegible]
3994	[illegible]	1	Trace not.	[illegible]	[illegible]
3995	[illegible]	2	0.0022	[illegible]	[illegible]
			0.0089	[illegible]	[illegible]
3996	[illegible]	2	0.0237	[illegible]	[illegible]
3997	[illegible]	3	0.0041	[illegible]	[illegible]
			0.0072	[illegible]	[illegible]
3998	[illegible]	3	0.0282	[illegible]	[illegible]

Analysis by [illegible]

Date 5-12-71

CH - XI

LABORATORY REPORT - STACK SAMPLING

Air Pollution Control Program, New Jersey State Dept. of Health

Name of Company NW BERGEN SEWAGE AUTH

Location of Stack END OF DOW AV, WALDWICK

Stack Designation INCINERATOR

Date Sampled 3 & 4 MAY 1971

Analysis Required CO_2 ORSAT (SLUDGE + AUX. FUEL)

Samples Collected by M. POLLAK Date (s)_____

CHAPTER cc XI

A.S. No.	Field No.	Run No.	RESULT OF ANALYSIS	Unit
3981	BLL #1	1	5.6	%
3985	BLL #2	2	10.6	%
3986	BLL #3	3	11.0	%

Analysis by Edward J. Hack

Date 5 May 1971

CHAPTER XI: INCINERATORS

DERIVATION OF EMISSION CONCENTRATION FORMULA

DEFINITIONS:

V.P. = Vapor pressure of water in inches of mercury

V_d = Volume of dry gas sampled at meter conditions in cubic feet

V_m = Volume of moisture remaining in metered gas at meter conditions in cubic feet

Wt = Weight of sample collected in grams

V_m = Volume of gas sampled as measured by meter in cubic feet

T_m = Temperature at meter in degrees F.

CO_2 = Percent carbon dioxide in flue gas excluding contribution of auxiliary fuel

V_{stp} = Volume of dry gas sampled at standard conditions

C = Emission concentration of dry flue gas in grains per standard cubic foot at standard conditions corrected to 12% carbon dioxide by volume excluding the contribution of auxiliary fuel

P_b = Barometric pressure in inches of mercury

Standard conditions are defined as 70° F. (530° R.) and one atmosphere pressure (14.7 psia or 760 mm of mercury)

DERIVATION:

1. The emission concentration (grains per standard cubic foot) in flue gas from a common or special incinerator is calculated for dry flue gas at standard conditions corrected to 12% carbon dioxide by volume excluding the contribution of auxiliary fuel.

2. To convert the weight of sample collected in grams to grains, multiply the weight by 15.43:

$$15.43 \times Wt \qquad (2)$$

3. To calculate the volume of moisture remaining in the metered gas at meter conditions, use the following equation:

$$M_m = \frac{V.P. \times V_m}{P_b} \qquad (3)$$

4. To calculate the volume of dry gas sampled at meter conditions subtract the volume of moisture remaining in the metered gas from the volume of gas sampled as measured by meter:

$$V_d = V_m - V_w \tag{4}$$

Substitute (3) for V_w in (4) to obtain (5).

5. $$V_d = V_m - \frac{V.P. \times V_m}{P_b} \tag{5}$$

6. To convert the volume of dry gas sampled at meter conditions to the volume of dry gas sampled at standard conditions, use Charles' Law:

$$V_{std} = V_d \times \frac{530}{(T_m + 460)} \tag{6}$$

Substitute (5) for V_d in (6) to obtain (7).

$$V_{stp} = \left[V_m - \frac{V.P. \times V_m}{P_b}\right] \times \frac{530}{(T_m + 460)} \tag{7}$$

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Simplify (7) to obtain (8).

8. $$V_{stp} = \frac{530 \times V_m \times (P_b - V.P.)}{P_b \times (T_m + 460)} \tag{8}$$

9. To calculate the emission concentration in dry flue gas at standard conditions uncorrected to 12% carbon dioxide by volume, divide (2) by (8) to obtain (9):

$$C = \frac{15.43 \times Wt \times P_b \times (T_m + 460)}{530 \times V_m \times (P_b - V.P.)} \tag{9}$$

10. To correct the emission concentration in dry flue gas at standard conditions to 12% carbon dioxide by volume excluding the contribution of auxiliary fuel, multiply (9) by $(12/CO_2)$ to obtain (10):

$$C = \frac{15.43 \times Wt \times P_b \times (T_m + 460) \times 12}{530 \times V_m \times (P_b - V.P.) \times CO_2} \tag{10}$$

11. Combine constant terms in (10) to obtain (11):

$$= \frac{0.3494 \times Wt \times P_b \times (T_m + 460)}{V_m \times (P_b - V.P.) \times CO_2} \tag{11}$$

STATE OF NEW JERSEY
AIR POLLUTION CONTROL PROGRAM
STACK TESTING
EMISSION CONCENTRATION REPORT

PLANT	
STREET	
CITY	
INCINERATOR	
N.J. No.	
CHAPTER No.	

FIELD & LAB DATA	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5
DATE					
Wt (grams)	0.0169	0.0348	0.0395		
P_b (inches of mercury)		~~29.70~~	~~29.70~~		
T_m (degrees F.)	80	78	78		
V_m (cubic feet)	40.451	41.740	38.708		
P_b (inches of mercury)		---	---		
V.P. (inches of mercury)		—	—		
CO_2 (percent)	7.0	5.1	4.0		
C (GRAINS/SCF)	0.0196	0.031	0.048		
ALLOWABLE (GRAINS/SCF)					

$$C = \frac{0.3494 \times Wt \times P_b \times (T_m + 460)}{V_m \times (P_b - V.P.) \times CO_2}$$

CALCULATIONS PERFORMED BY: Mark Pollak.

DATE: May 14, 1971

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APPENDIX G

Region II Office
26 Federal Plaza
New York, New York 10007

April 7, 1971

Disposal of Sewage Sludge

Dr. John T. Middleton
Acting Commissioner, APCO

1. The attached letter from the Director of the Interstate Sanitation Commission stresses the immediate importance of considering alternatives to the ocean dumping of sewage sludge. In this regard, it echoes an April 3 editorial in the New York Times which points out the need for research and development work on such alternatives.

2. Because one obvious alternative involves incineration, with its inherent air pollution potential, it is respectfully suggested that the Air Pollution Control Office combine with other interested EPA programs to begin an effort aimed at developing a method for sewage sludge disposal which does not adversely affect any aspect of the environment. This suggestion is in keeping with our memorandum, to you, of March 9.

Kenneth L. Johnsen
Regional Air Pollution Control Director

Attachment

INTERSTATE SANITATION COMMISSION

10 COLUMBUS CIRCLE • NEW YORK, N. Y. 10019

AREA CODE 212-582-0380

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THOMAS R. GLENN, JR.
DIRECTOR-CHIEF ENGINEER

April 1, 1971

Mr. Kenneth L. Johnson, Director
Regional Air Pollution Control
Environmental Protection Agency-APCO
26 Federal Plaza, Room 832
New York, New York - 10006

Dear Mr. Johnson:

The President's Environmental Quality Council recently stated that the disposal of sewage sludge at sea should be phased out as soon as possible and then stated that the sludge should not be incinerated as it would cause an air pollution problem. The Council did not recommend alternatives for these heavily urbanized areas.

In New Jersey, within our jurisdiction, there are eight sewage treatment plants that dispose of their sludge by barging ten miles to sea. The total amount is about five thousand tons per day. Seven of these treatment plants are under orders by the State of New Jersey to upgrade their treatment plants to full secondary treatment. The disposal of sludge must be part of this overall project.

The Rahway Valley Treatment Plant is already under construction. The Linden-Roselle Treatment Plant had its plans completed and approved but has now been asked to make other arrangements for disposal of sludge other than sludge digestion and disposal at sea. Many of the other plants are in the design stage.

The Commission's real concern is that with the knowledge that disposal of sludge will be phased out very suddenly, they might quickly turn to different forms of combustion, and this includes not only conventional types of incineration but

low pressure combustion types such as manufactured by Dorr-Oliver and Sterling Drug.

Although we are unable to obtain any data on the exhaust emissions from any of these devices, we feel sure that nitrous oxides will exceed any standards being considered. New standards for nitrous oxides probably will be passed and put into effect before some of these incinerators are completed and they may not be allowed to operate. The much larger volume of sludge from New York City will be an even larger problem.

Another practical problem is that with all these individual plants developing incinerators, they would hardly get up to temperature before they would use up the sludge and this would make the operation difficult without causing severe odor problems. In other areas of New York State and Connecticut where barging at sea was not previously practiced, many incinerators are being constructed when upgrading their treatment plants and will become a problem immediately when air pollution standards are set.

We therefore urge that the Air Quality Office of EPA make an immediate survey of the emissions of some of these recently installed sludge combustion devices. This information may prevent changing a water pollution problem into an air pollution problem.

I should emphasize again that we cannot wait until the official announcement to phase out sludge disposal at sea before setting a policy on incinerators as decisions are already being made. Even in a matter of a few weeks, it will be too late in many cases.

Very truly yours,

Thomas R. Glenn, Jr.

Thomas R. Glenn, Jr.
Director & Chief Engineer

APPENDIX I

ENVIRONMENTAL PROTECTION AGENCY
Research Triangle Park, North Carolina 27711

REPLY TO ATTN OF: DD/DHER

DATE: 2/2/72

SUBJECT: Hazards of Emissions from Sewage Sludge Emissions

TO: Ken Johnson
Regional Director for Air and
Water Programs
Region II Office
26 Federal Plaza
New York, New York 10007

In our meeting of September 27, 1971, you provided a list of elements found in stack samples taken from two modern sewage sludge incinerators. These elements are:

Zinc
* Cadmium
* Arsenic
Phosphorus
Iron
Magnesium
* Beryllium
Copper
Silver
* Nickel
* Cobalt
* Lead
* Chromium
* Vanadium
Strontium
* Mercury

I discussed the fact that the elements identified by the asterisk tend to be biologically non-degradable, are toxic at certain concentrations in human tissue, would add to the human body burden from other sources and as such are likely to represent a true health hazard, especially if sewage sludge incinerators proliferate in urban areas.

I also discussed with you the fact that many synthetic organic compounds are likely to become concentrated in sewage sludge and that these compounds, such as PCB, will represent another class of hazards if incinerated and released to the atmosphere. These compounds were not analyzed in the stack samples.

/s/

Carl M. Shy, M. D.
Deputy Director
Division of Health Effects Research

EPA Form 1320-6 (11-71)

1 Accession Number: W

2 Subject Field & Group: 5 D

SELECTED WATER RESOURCES ABSTRACTS
INPUT TRANSACTION FORM

5 Organization
Environmental Protection Agency
Office of Research & Monitoring
~~Washington, D. C. 20460~~

6 Title
SEWAGE SLUDGE INCINERATION

10 Author(s)
EPA Task Force

16 Project Designation

21 Note

22 Citation
Environmental Protection Agency Report No. EPA-R2-72-040, August 1972

23 Descriptors (Starred First)
* Sludge Incineration
* Air Pollution
Effects
* Pesticide Removal
Heavy Metals
Ultimate Disposal
Sludge Disposal

25 Identifiers (Starred First)
* Multiple Hearth Furnances
* Fluidized Bed Incinerators
Polychlorinated Biphenyls (PCB)
Stack Emissions
Ocean Disposal
Particulate Removal

27 Abstract
A Task Force was established within the Environmental Protection Agency to evaluate sludge incineration as an acceptable alternative to sea disposal. Multiple-hearth and fluidized bed furnances, containing scrubbing devices for particulate removal, were selected for performance evaluation. The sludge, particulate, stack gas, scrubbing liquid, and ash were sampled, and analyzed for heavy metals, pesticides and oxides of nitrogen and sulfur. The results indicated that incinerators are capable of achieving low emission concentrations for the common pollutants. Particulate samples showed a measurable concentration of lead. The ash samples normally showed a higher concentration of the heavy metals when compared with the sludge samples, however, mercury was one of the exceptions and was not detectable in the ash sample and assumed as lost to the stack gases. The pesticides and PCB, present in the sludge, were not detectable in either the ash or the scrubbing water, and indicated complete destruction. The study demonstrated that well designed and operated municipal sewage sludge incinerators can meet the most stringent existing particulate emission control regulation.

Org. K. Johnson
Institution Environmental Protection Agency, Region II

WR:102 (REV. JULY 1969)
WRSIC

SEND, WITH COPY OF DOCUMENT, TO: WATER RESOURCES SCIENTIFIC INFORMATION CENTER
U.S. DEPARTMENT OF THE INTERIOR
WASHINGTON, D. C. 20240

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* GPO: 1970-389-930

APPENDIX A

TABLE: CONCENTRATIONS OF METALS IN SLUDGES

(Mg/g)

	Monterey, California 10/13/71	Middlesex County New Jersey 10/27/71	Joint Meet. N. J. 10/25/71	Passaic Valley N. J. 11/1/71	Bergen Co. N.J. 10/26/71
Ag	0.03	N. D.	0.08	N. D.	0.08
Al	2.40	3.00	5.20	3.40	12.6
Ba	0.76	0.38	1.42	0.48	1.20
Be	N. D.	N. D.	N. D.	N. D.	N. D.
B	0.70	0.70	1.30	0.90	1.46
Cd	N. D.	N. D.	N. D.	N. D.	N. D.
Co	0.26	N. D.	0.34	0.20	0.40
Cr	N. D.	N. D.	1.80	0.86	7.60
Cu	0.60	0.60	2.50	0.62	1.52
Fe	2.60	4.20	10.4	2.40	11.8
Hg	A. P.	A. P.	A. P.	A. P.	A. P.
Mn	0.07	N. D.	0.80	0.32	9.40
Mo	N. D.	N. D.	N. D.	N. D.	N. D.
Ni	0.22	N. D.	0.38	0.32	0.38
Pb	0.60	N. D.	0.80	1.60	1.70
P	7.20	7.00	15.6	7.60	34.2
Sr	N. D.	N. D.	N. D.	N. D.	N. D.
V	N. D.	N. D.	0.26	N. D.	0.28
Zn	1.95	1.90	2.20	2.20	2.80

N. D. Not Detected.

A. P. Analysis Pending.

SELECTED WATER RESOURCES ABSTRACTS INPUT TRANSACTION FORM	W 72 12631

SEWAGE SLUDGE INCINERATION, PB. 211323

EPA Program Element B 12043

Environmental Protection Agency, Washington, D. C., Task Force of Sewage Sludge Incineration

Environmental Protection Agency Report No. EPA-R2-72-040, August 1972, 89 p, 2 fig, 10 tabs, 5 ref, 9 append

A Task Force was established within the Environmental Protection Agency to evaluate sludge incineration as an acceptable alternative to sea disposal. Multiple-hearth and fluidized bed furnances, containing scubbing devices for particulate removal, were selected for performance evaluation. The sludge, particulate, stack gas, scrubbing liquid, and ash were sampled, and analyzed for heavy metals, pesticides and oxides of nitrogen and sulfur. The results indicated that incinerators are capable of achieving low emission concentrations for the common pollutants. Particulate samples showed a measurable concentration of lead. The ash samples normally showed a higher concentration of the heavy metals when normally showed a higher concentration of the heavy metals when compared with the sludge samples, however, mercury was one of the exceptions and was not detectable in the ash sample and assumed as lost to the stack gases. The pesticides and PCB, present in the sludge, were not detectable in either the ash or the scrubbing water, and indicated complete destruction. The study demonstrated that well designed and operated municipal sewage sludge incinerators can meet the most stringent existing particulate emission control regulation. (K. Johnson--EPA)

*Incineration, *Ultimate Disposal, *Sludge Disposal, *Waste treatment, Air pollution effects, Sludge, Pesticide Removal, Heavy metals, Polychlorinated biphenyls

*Multiple hearth furnances, *Fluidized bed incinerators, Stack emissions, Ocean disposal, Particulate removal

05D, 05E

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